Pathogens and Ecosystem Management in the Oceans

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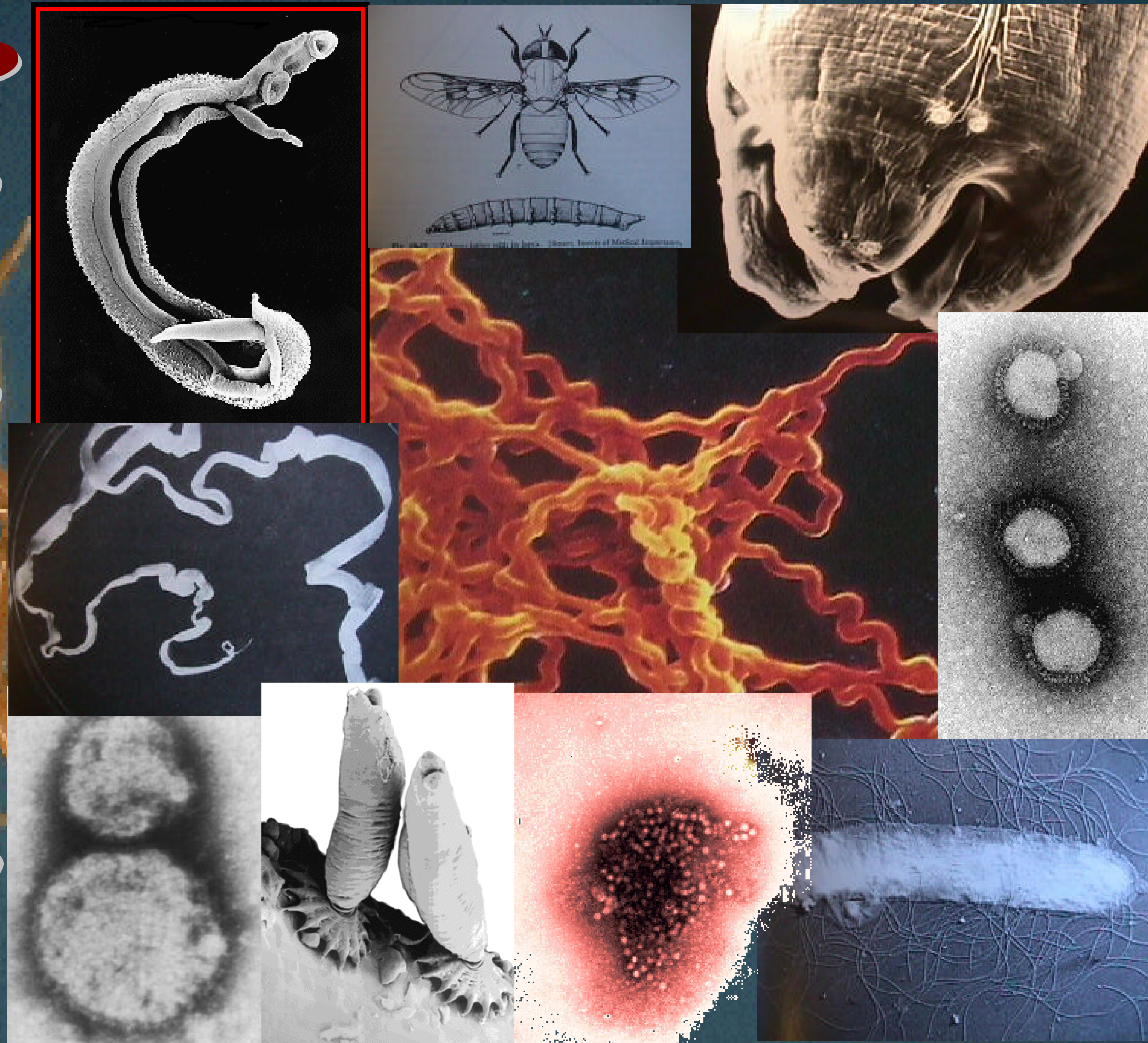
EEB, Eno Hall

Parasites

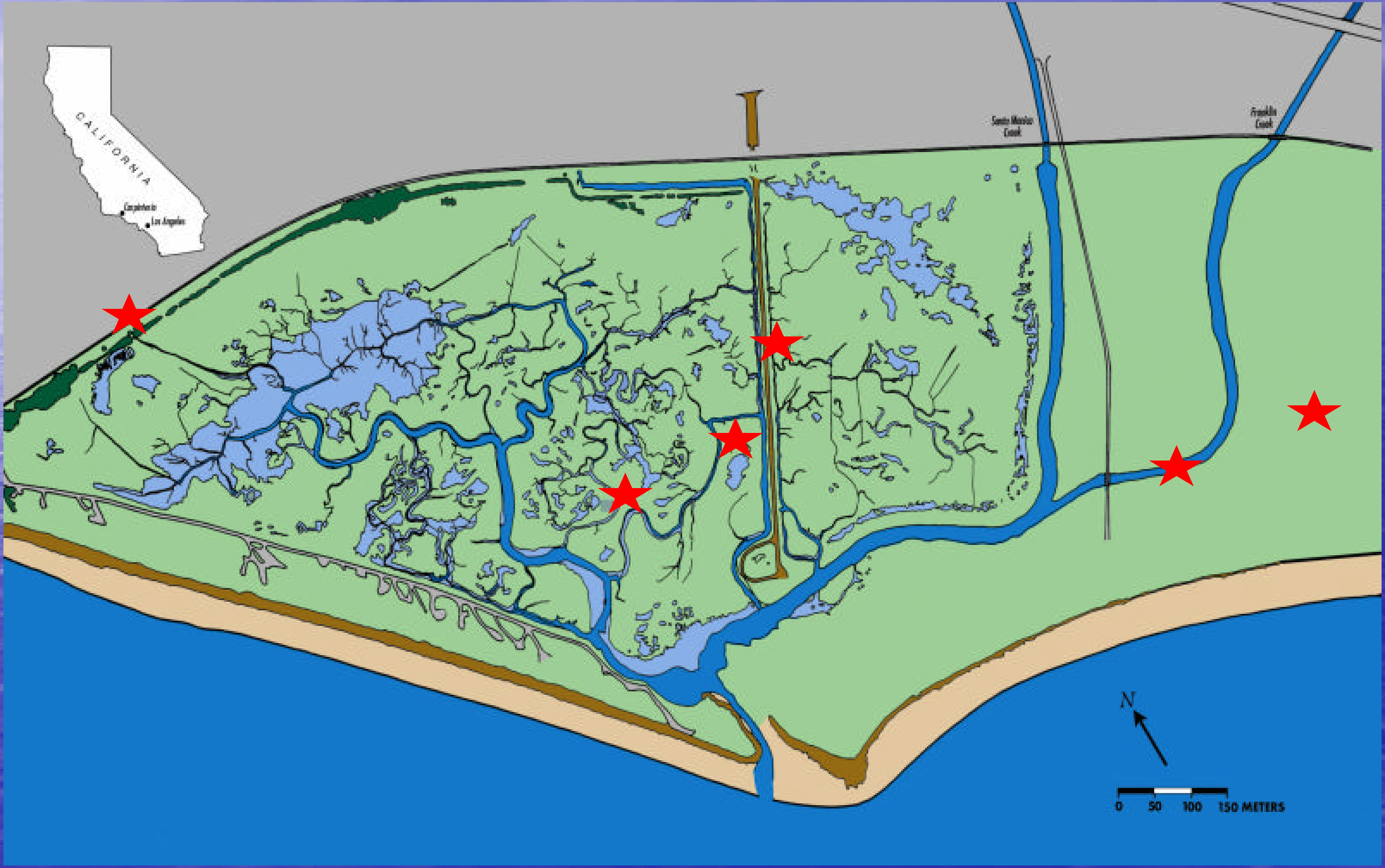


Overview

- There is a huge diversity of parasites and pathogens in all ecosystems
- They have significant impact as regulators of hosts and perhaps also of pollutants
- Dynamics of epidemics is well understood – but they might happen much more quickly in the oceans.
- Pathogens may be best controlled by predators
- A healthy ecosystem (or a well balanced one) is one that is full of parasites!!

UCSB
Salt marsh
Parasite food-web
Team in action.

Carpinteria Salt Marsh
Santa Barbara County CA USA

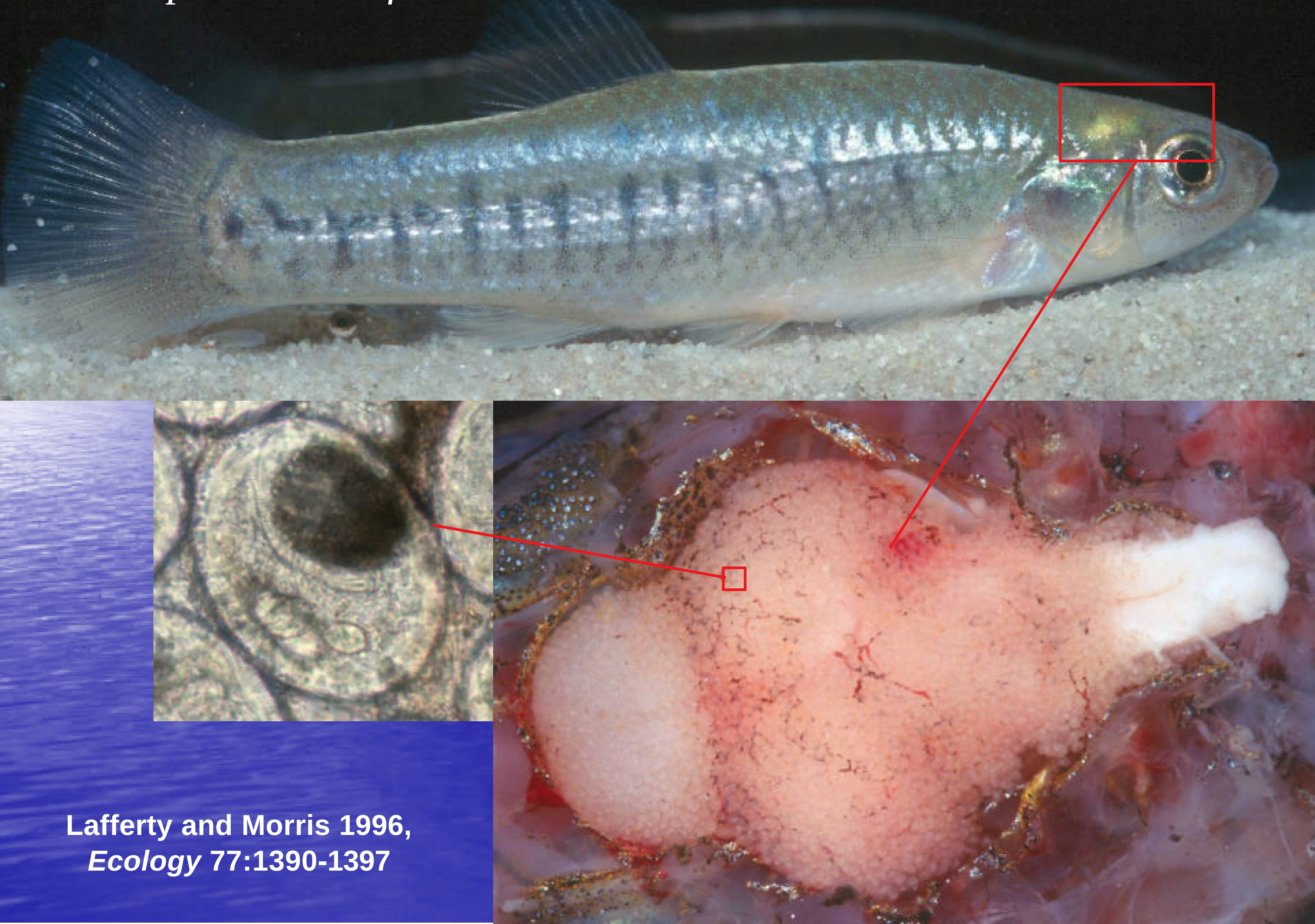



VAUGHAN
FINE TOOLS SINCE 1869
SuperSteel
MADE IN U.S.A.
CORPORATION

All trematodes identified to species

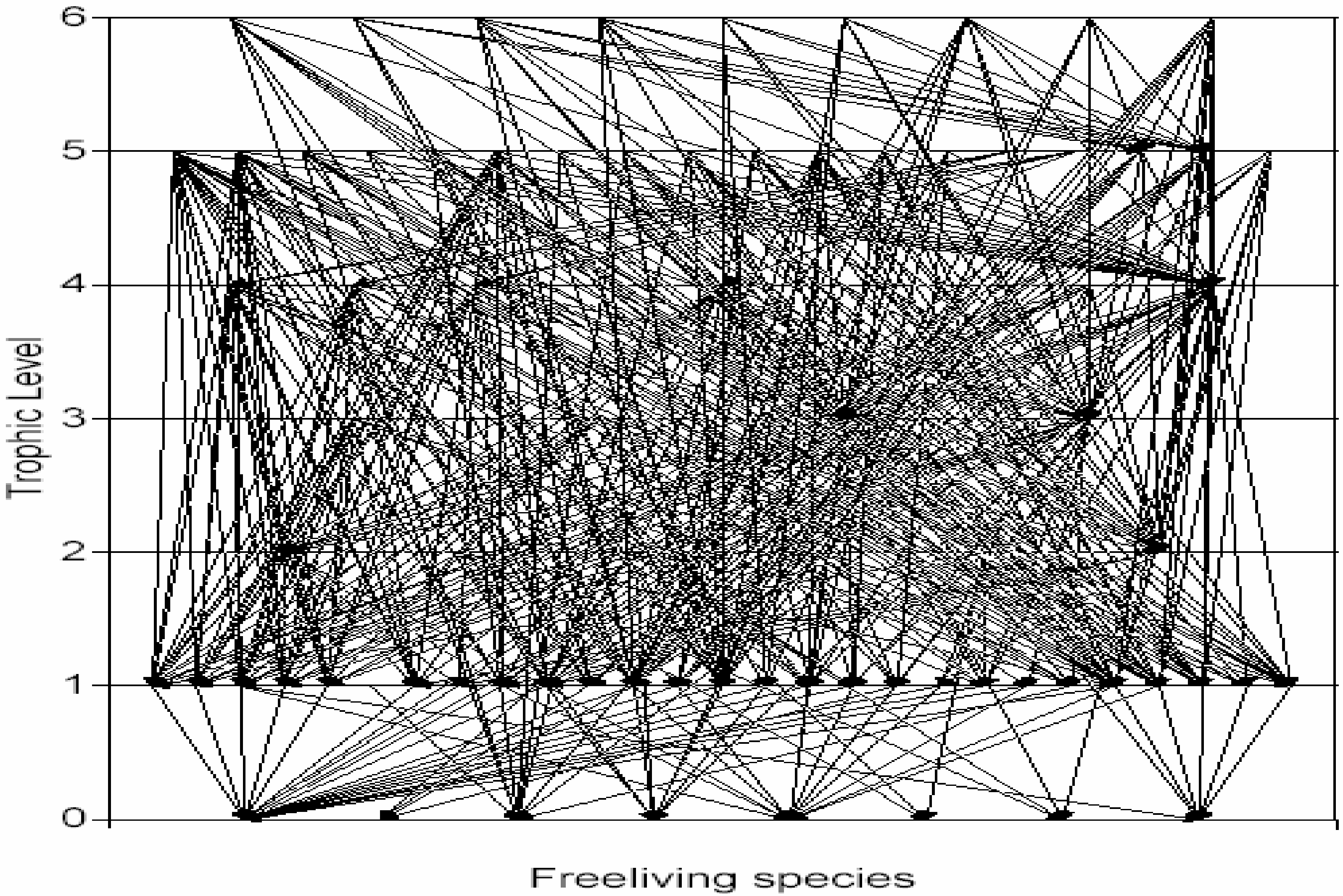

Digenean cercariae

Euhaplorchis californiensis metacercariae coat the killifish's brain



Lafferty and Morris 1996,
***Ecology* 77:1390-1397**

Carpinteria salt marsh food web – without parasites



Little Rock Lake Food Web
92 Taxa with 997 Feeding Links

Martinez, N.D. 1991. Artifacts or attributes? Effects of resolution on the Little Rock Lake food web. *Ecological Monographs* 61:367-392

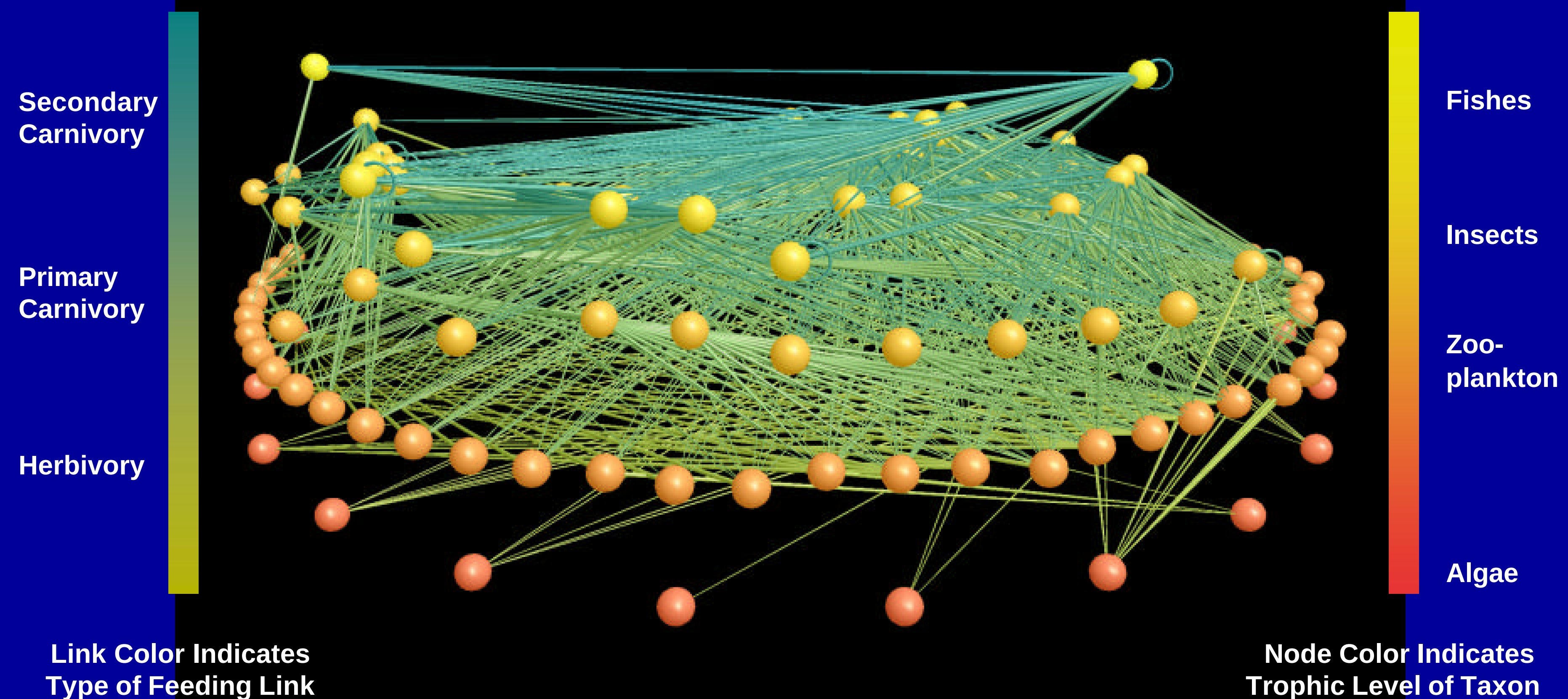
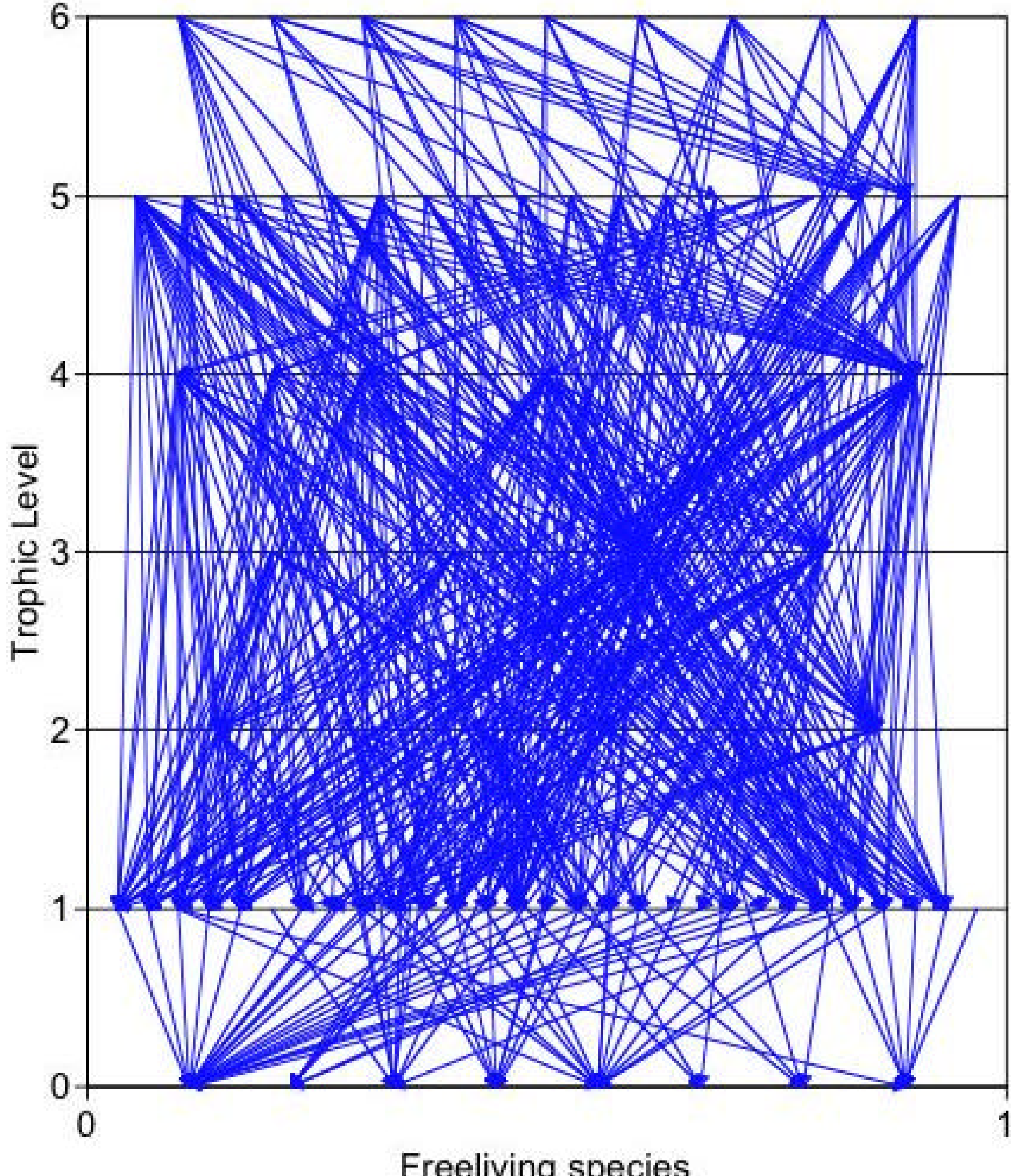
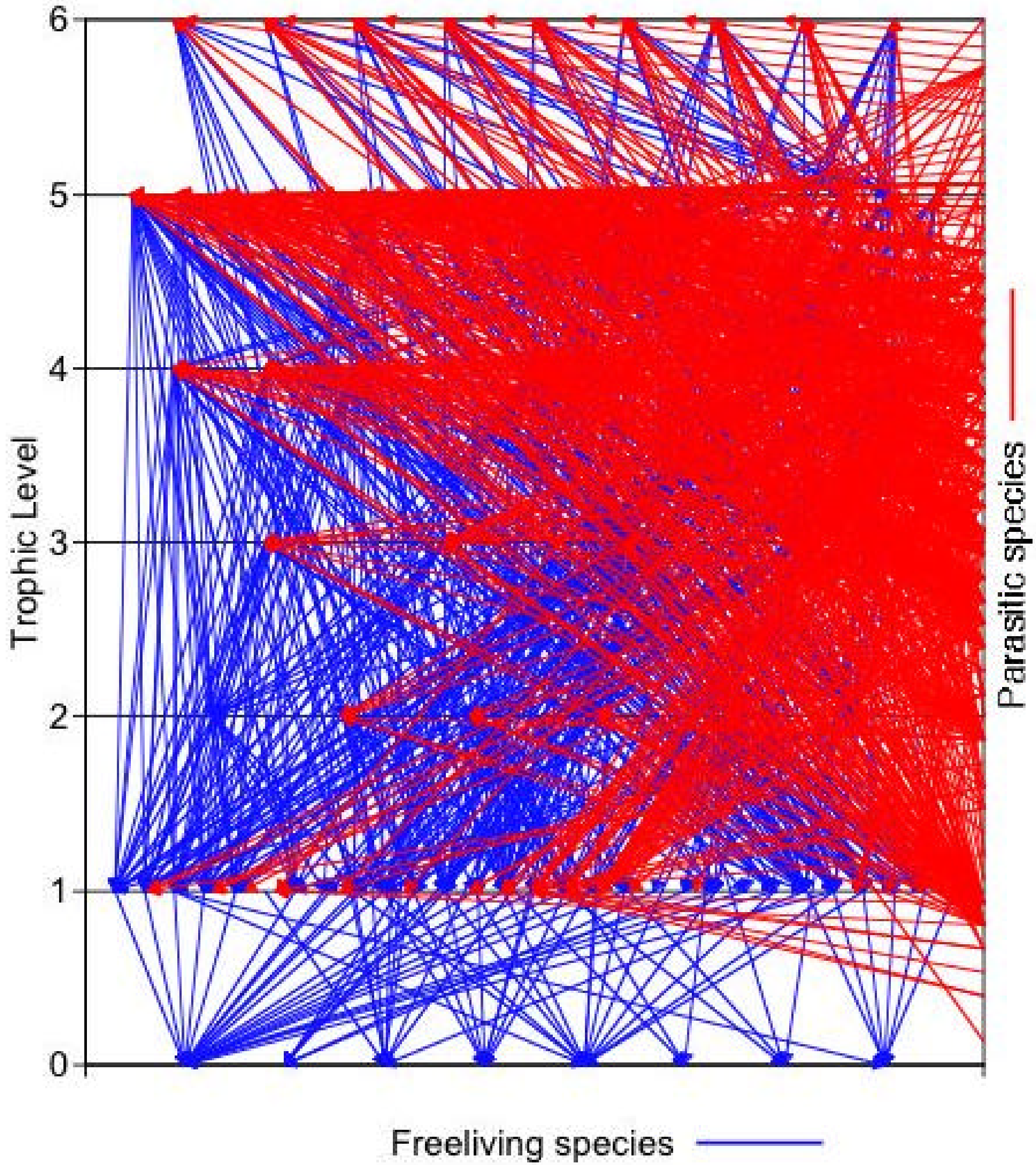


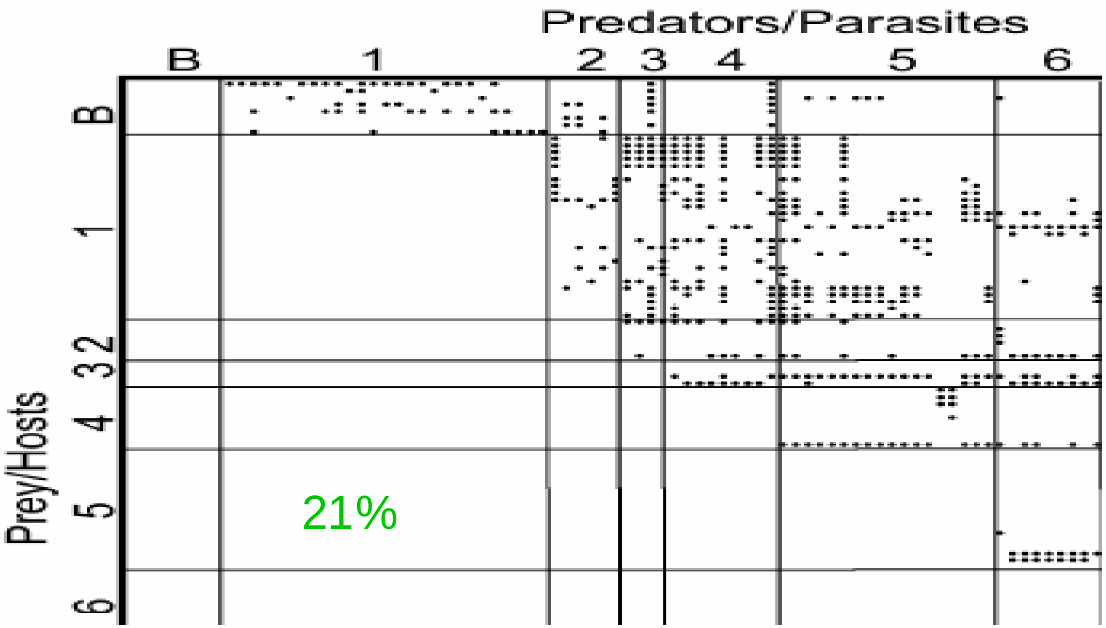
Image produced with FoodWeb3D, R.J. Williams

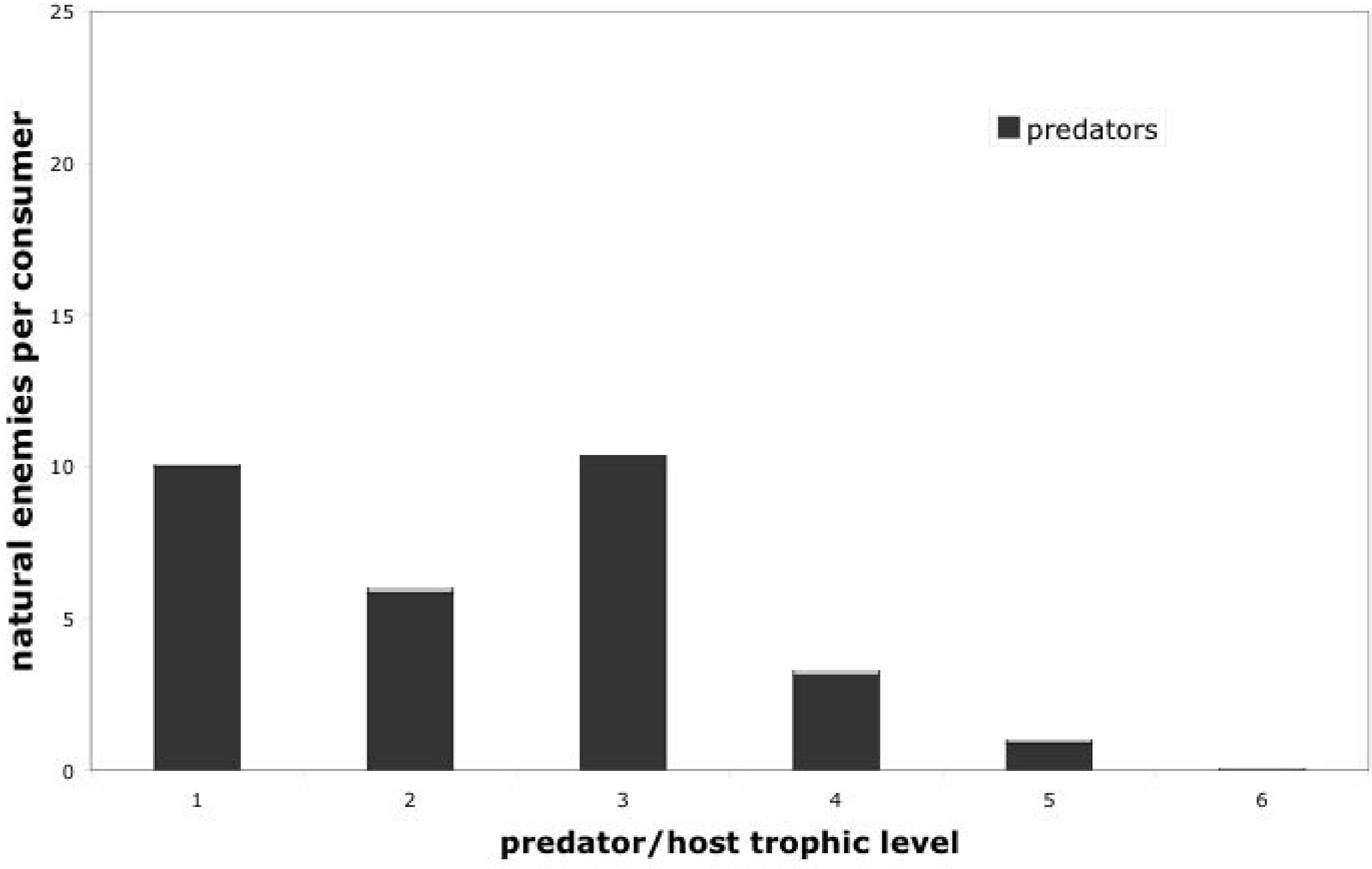

Trophic Level
6
5
4
3
2
1
0
0
1
Freeliving species



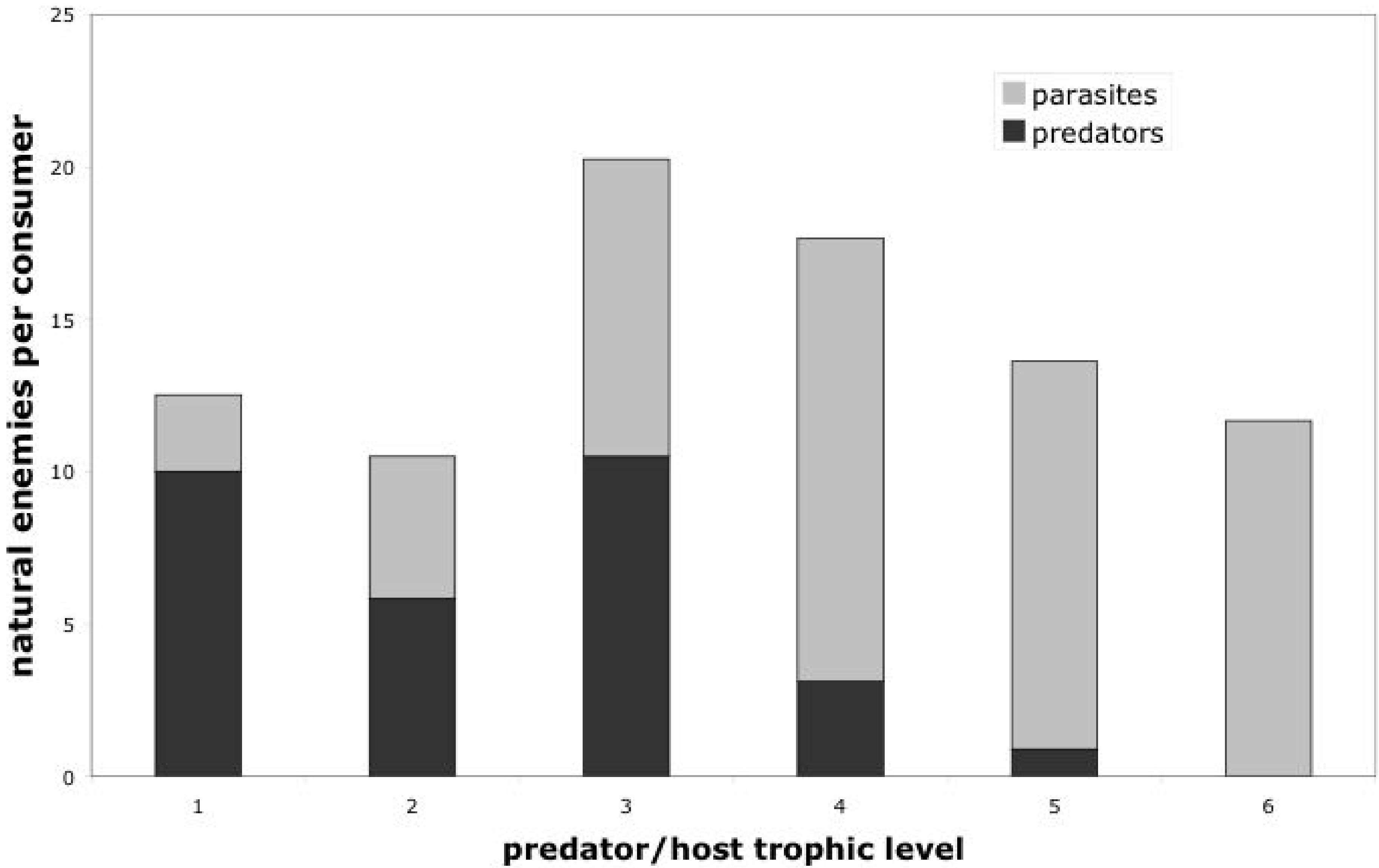
Trophic Level
6
5
4
3
2
1
0
Parasitic species
Freeliving species

Carpinteria Salt marsh food web



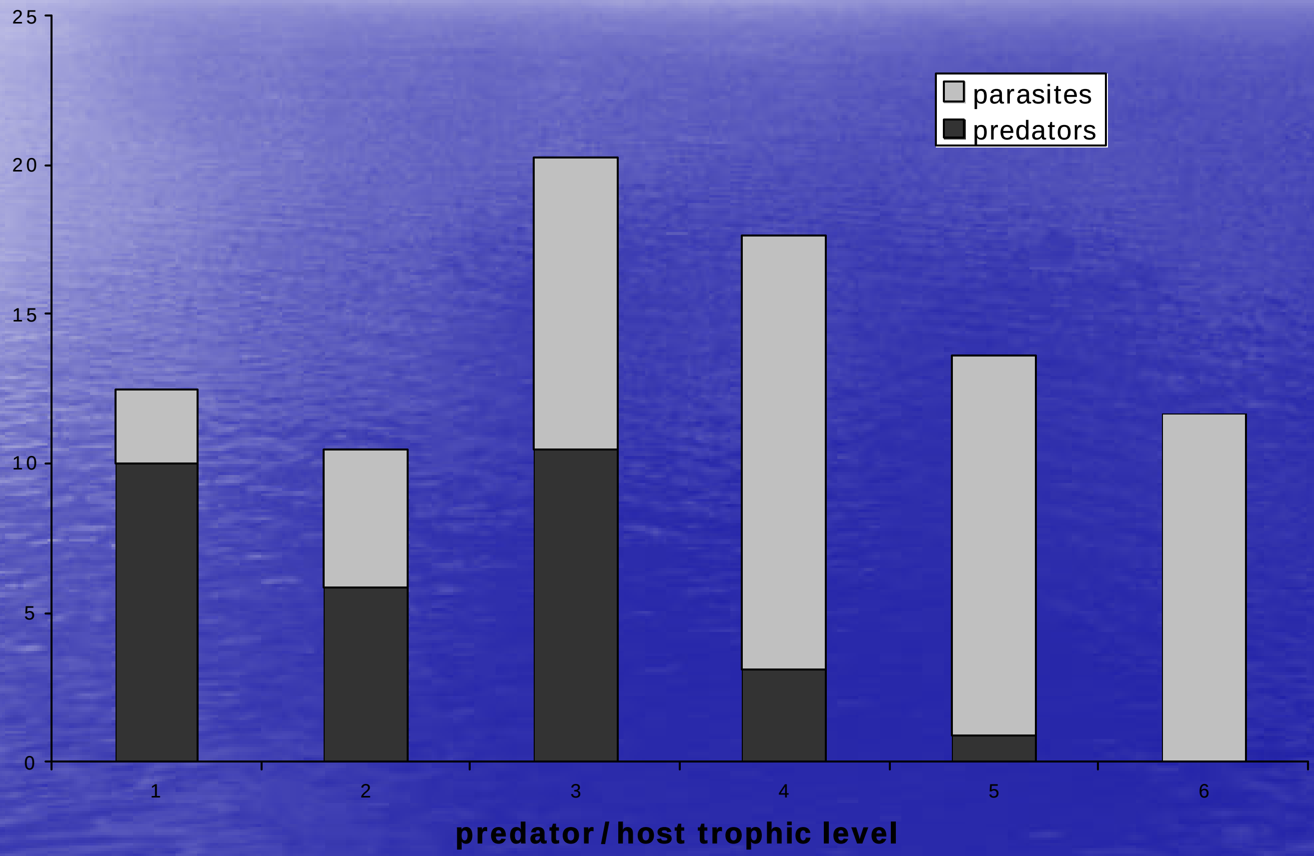


25
20
15
10
5
0
natural enemies per consumer
predators
1
2
3
4
5
6
predator/host trophic level



25
20
15
10
5
0
parasites
predators
natural enemies per consumer
1
2
3
4
5
6
predator/host trophic level

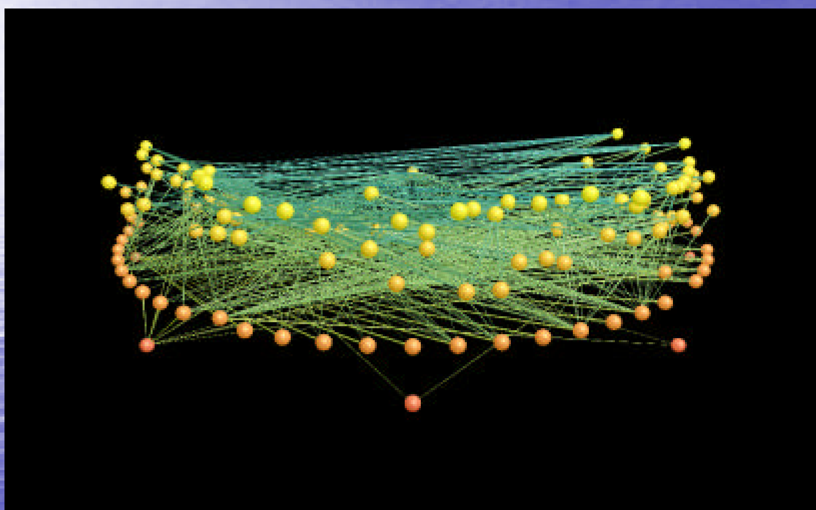
Average number of natural enemies per species on each trophic level



Predators decrease -> parasites and pathogens increase

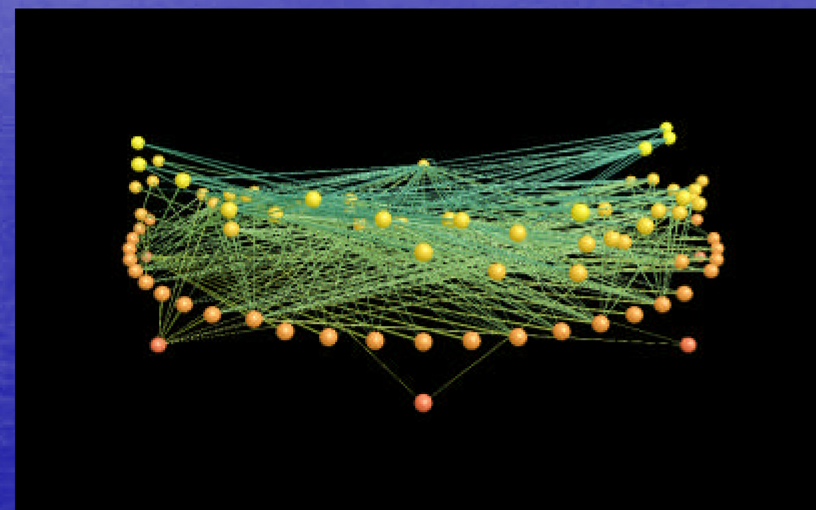
Low connectance webs, *C* < 0.10

Ythan Estuary



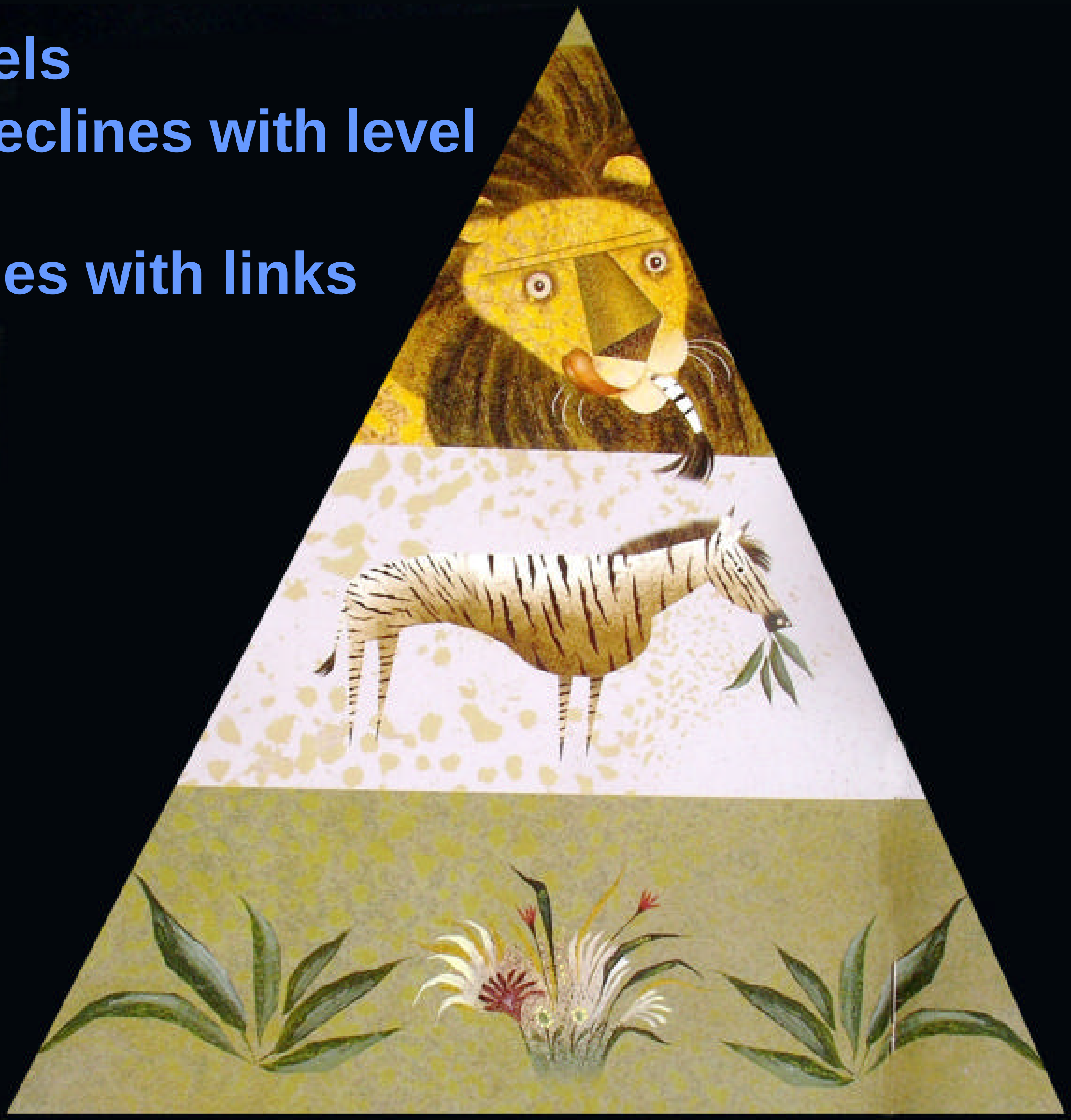
C = 0.04, *S* = 124, *L/S* = 4.7
Huxham et al. 1996

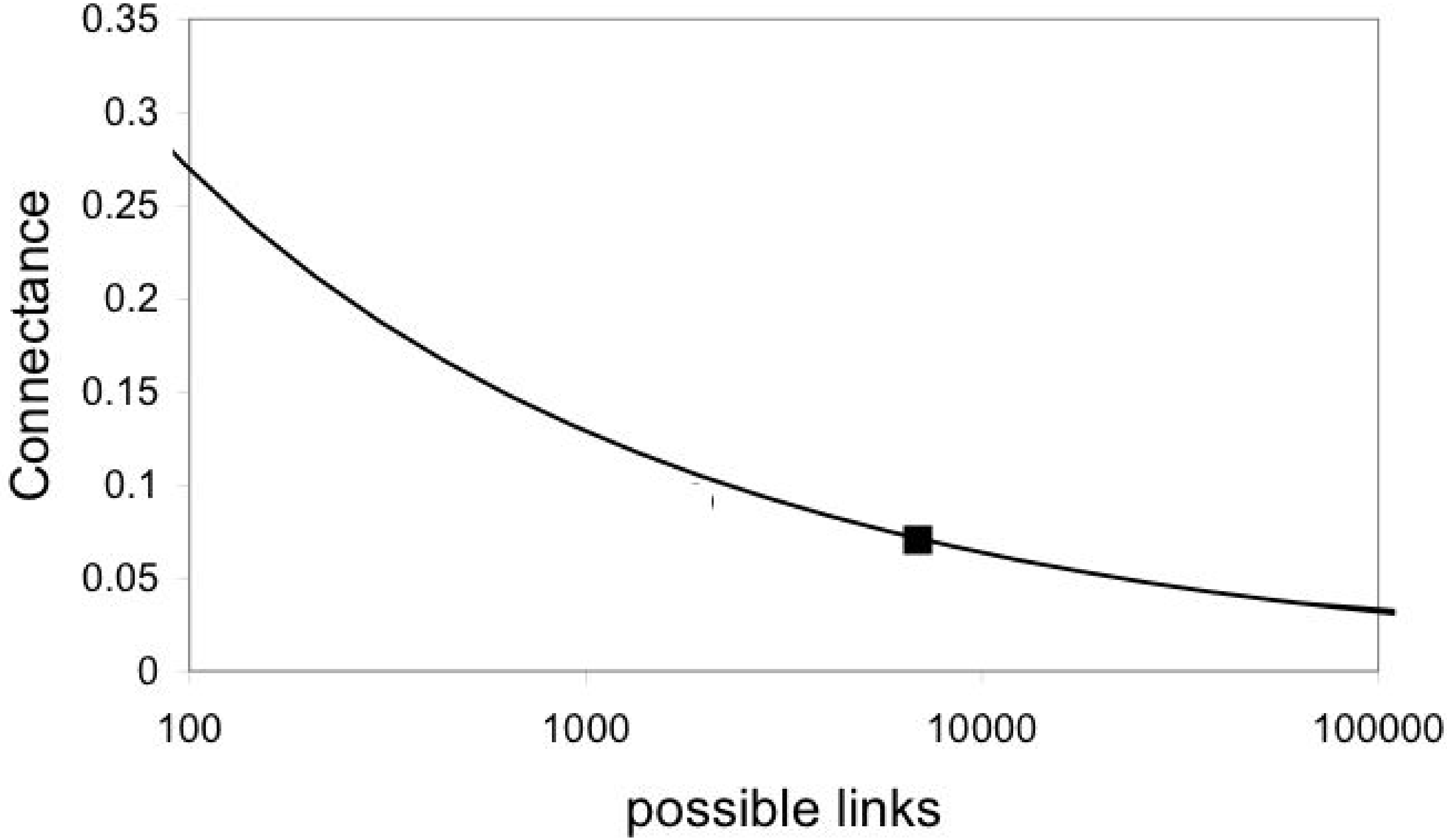
Ythan Estuary, no parasites

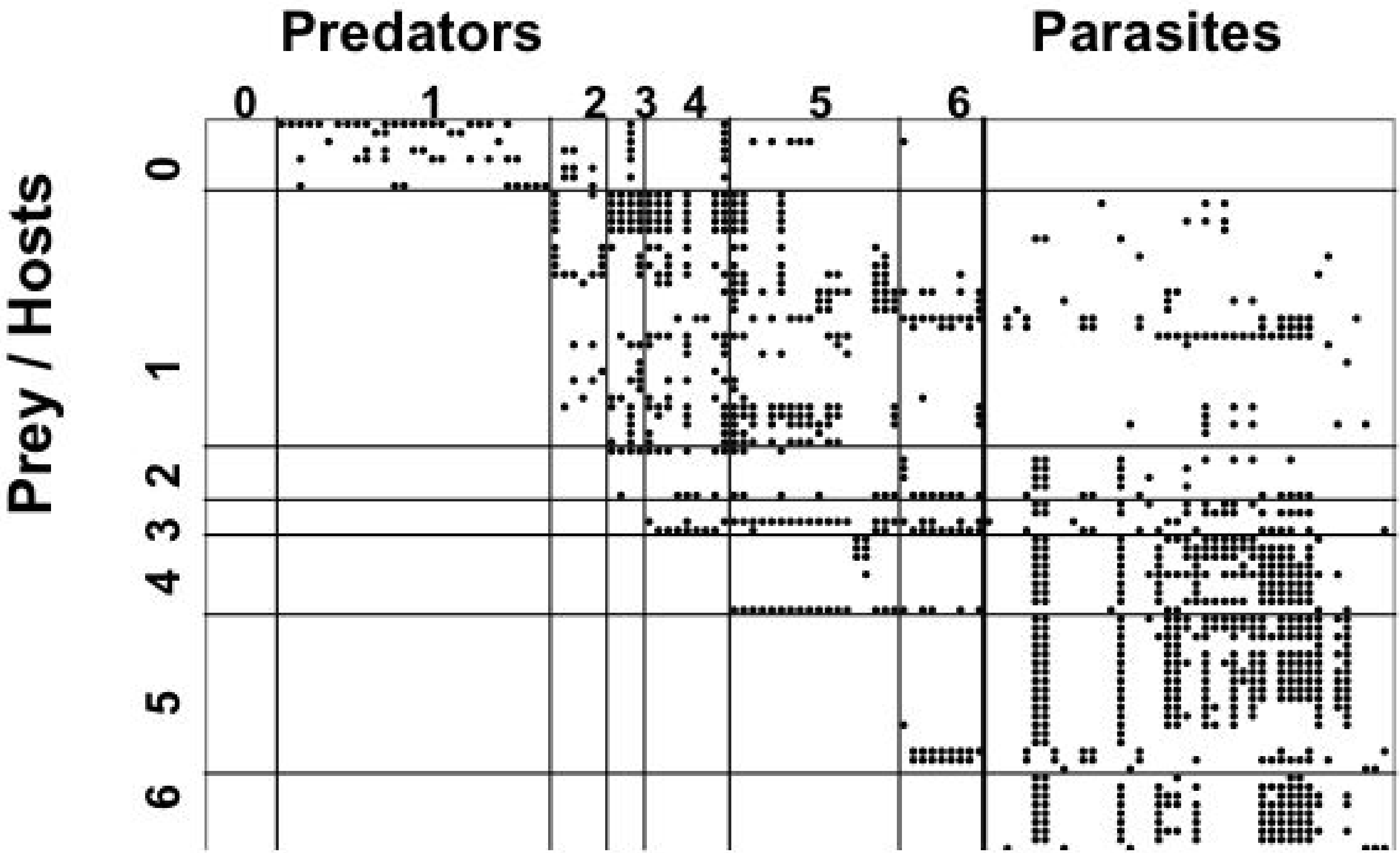


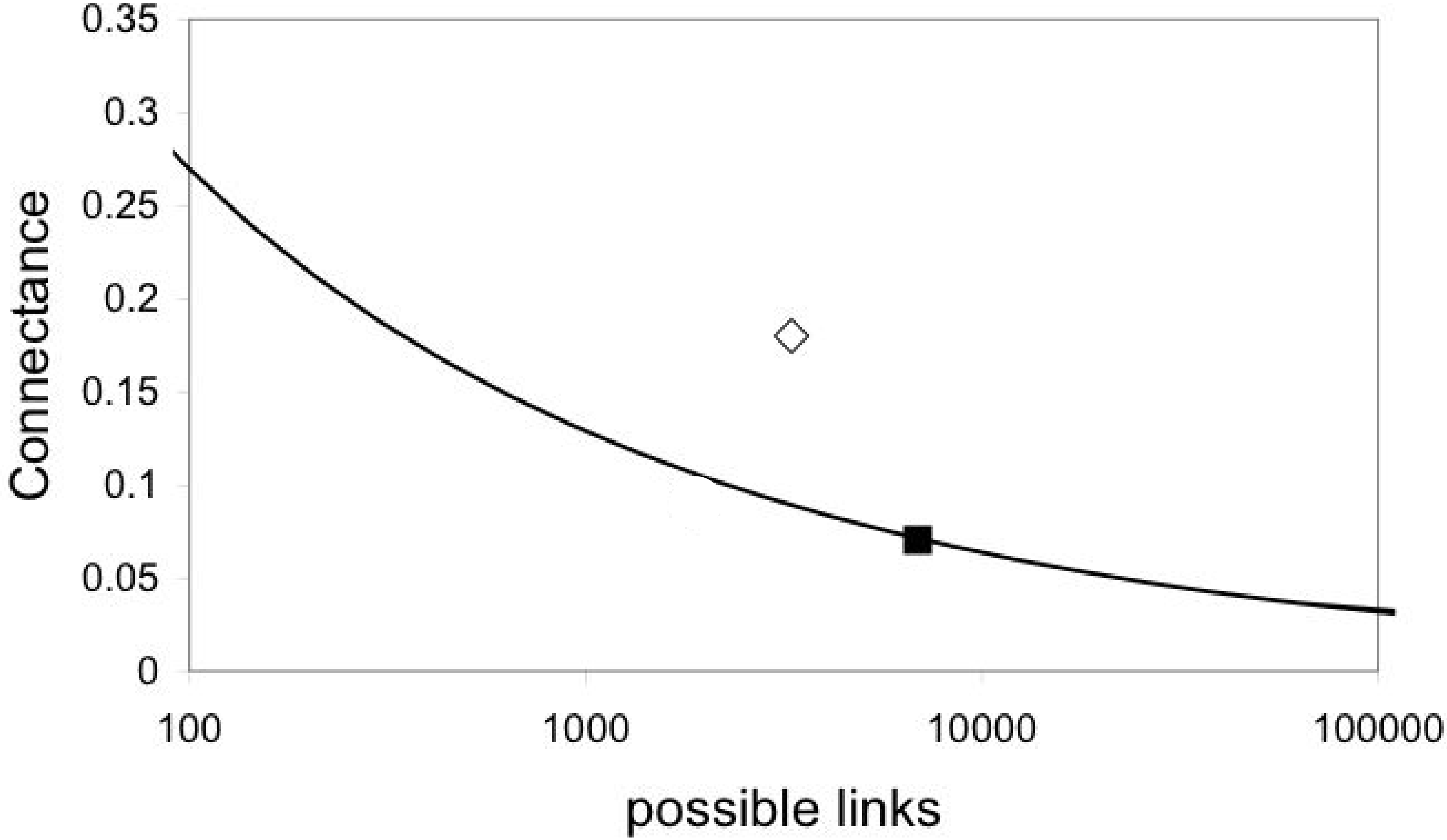
C = 0.06, *S* = 83, *L/S* = 4.8
Hall & Raffaelli 1991

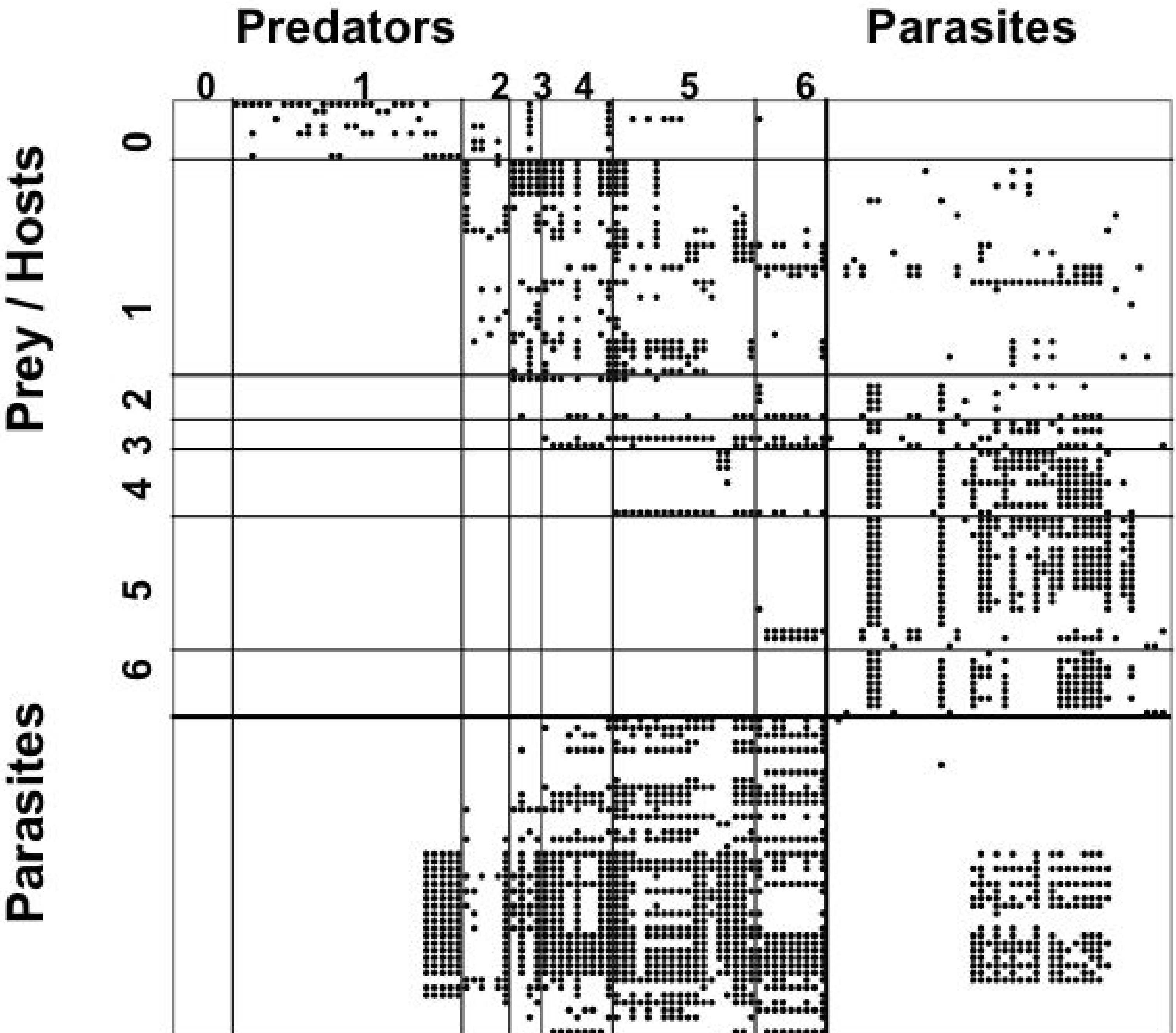
- 3-4 trophic levels
- Vulnerability declines with level
- Links = $S^{1.4}$
- Stability declines with links



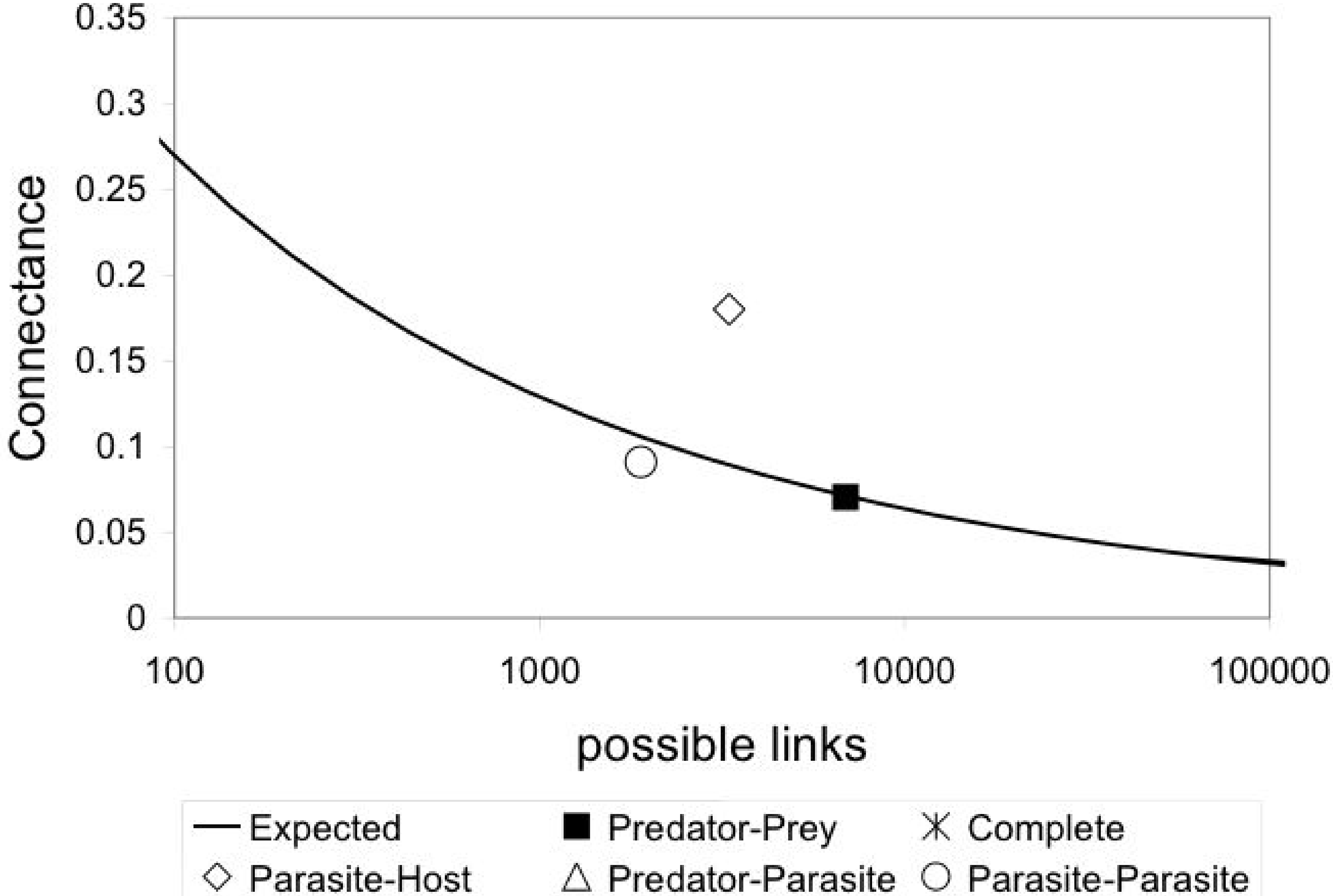

Connectance
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
100
1000
10000
100000
possible links

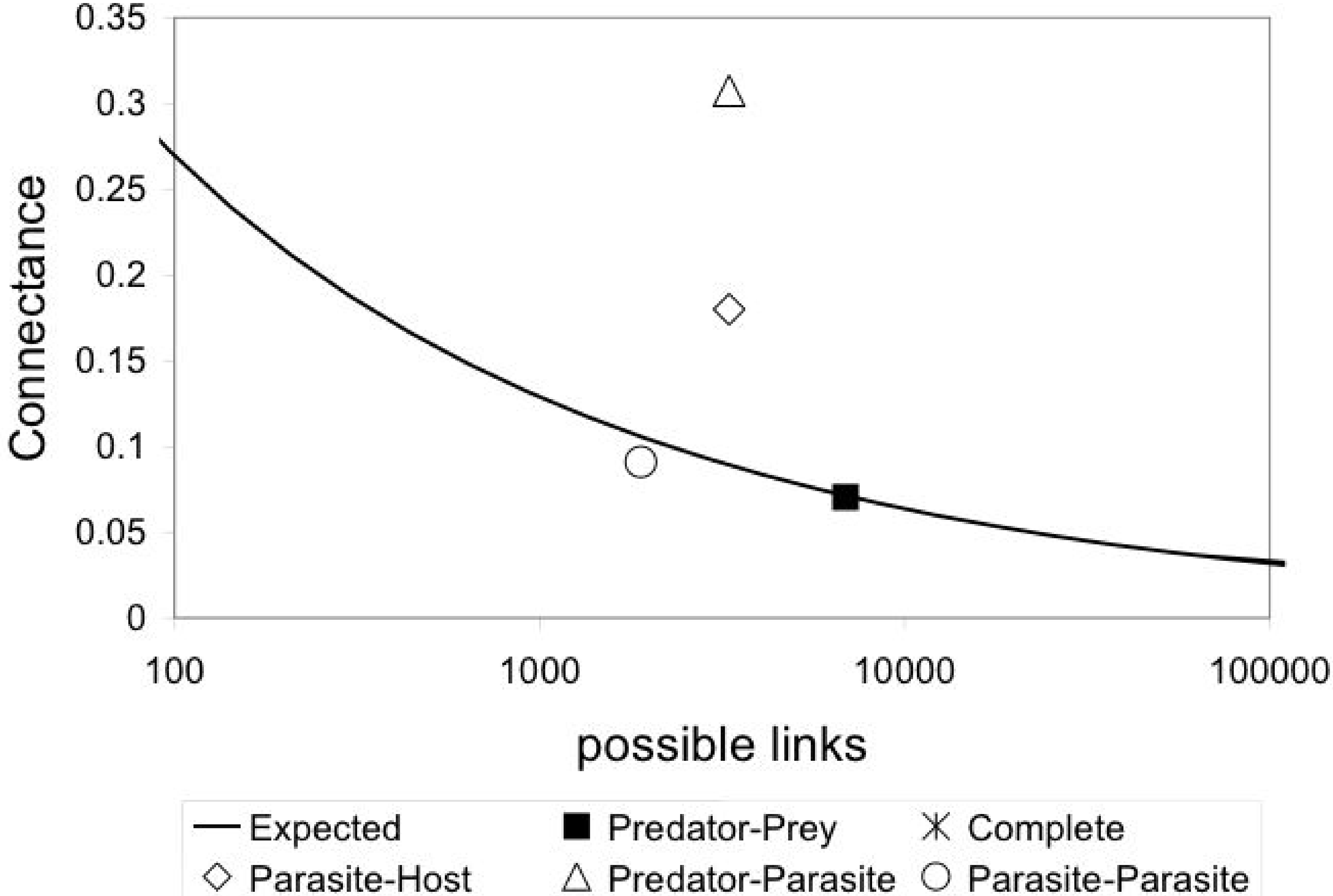

Predators
Parasites
0
1
2
3
4
5
6
Prey / Hosts
0
1
2
3
4
5
6

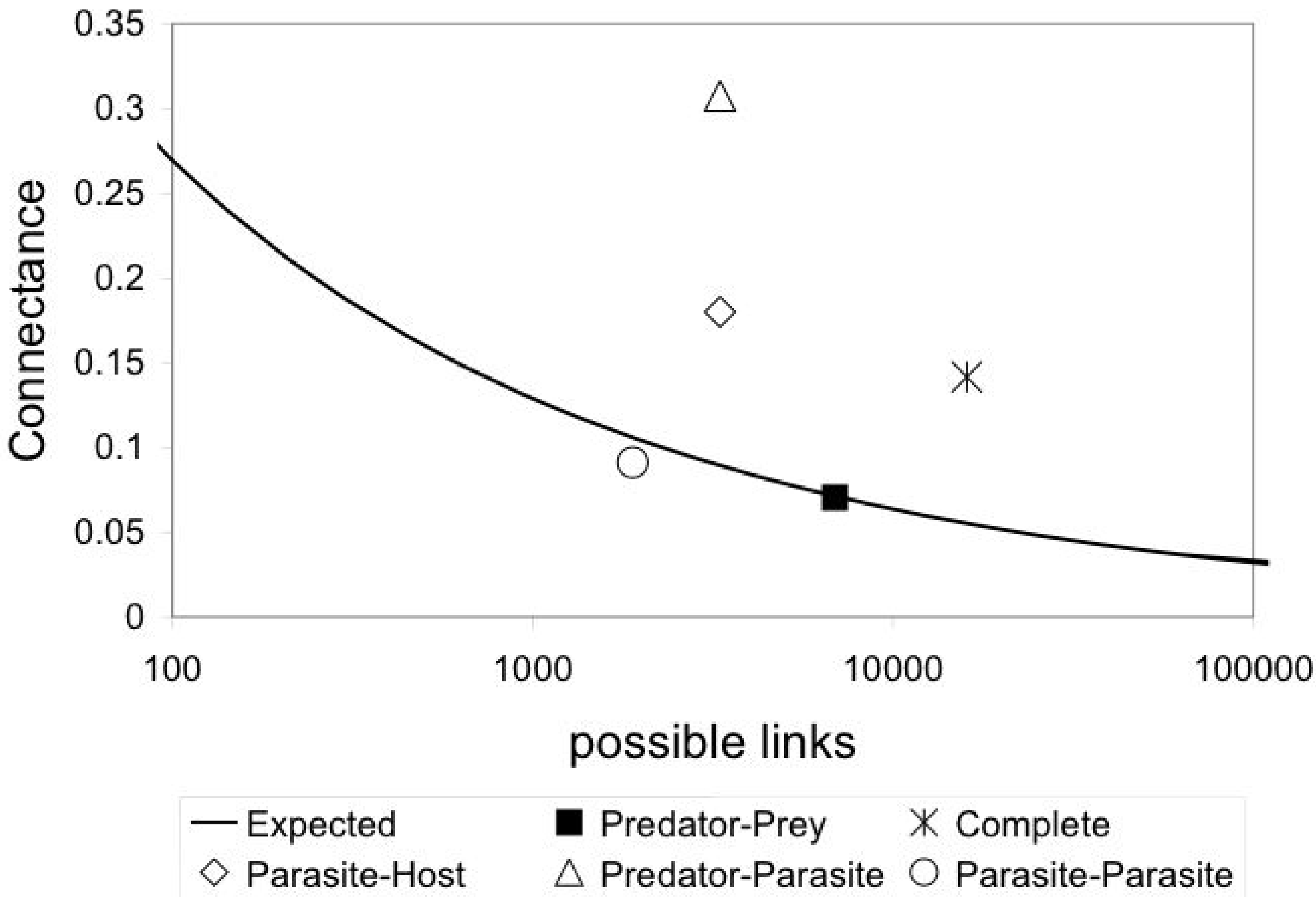

0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Connectance
100
1000
10000
100000
possible links



Predators
Parasites
0
1
2
3
4
5
6
Prey / Hosts
0
1
2
3
4
5
6
Parasites


0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Connectance
100
1000
10000
100000
possible links
Expected
Predator-Prey
Complete
Parasite-Host
Predator-Parasite
Parasite-Parasite


0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Connectance
100
1000
10000
100000
possible links
Expected
Predator-Prey
Complete
Parasite-Host
Predator-Parasite
Parasite-Parasite



0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Connectance
100
1000
10000
100000
possible links
Expected
Predator-Prey
Complete
Parasite-Host
Predator-Parasite
Parasite-Parasite

Biomass of trematodes = biomass of un-poached elephant populations / unit area

Birth rate of trematodes – one elephant / 24 hours….life expectancy weeks/ months

Genomic analyses of sediment in almost the same salt marsh

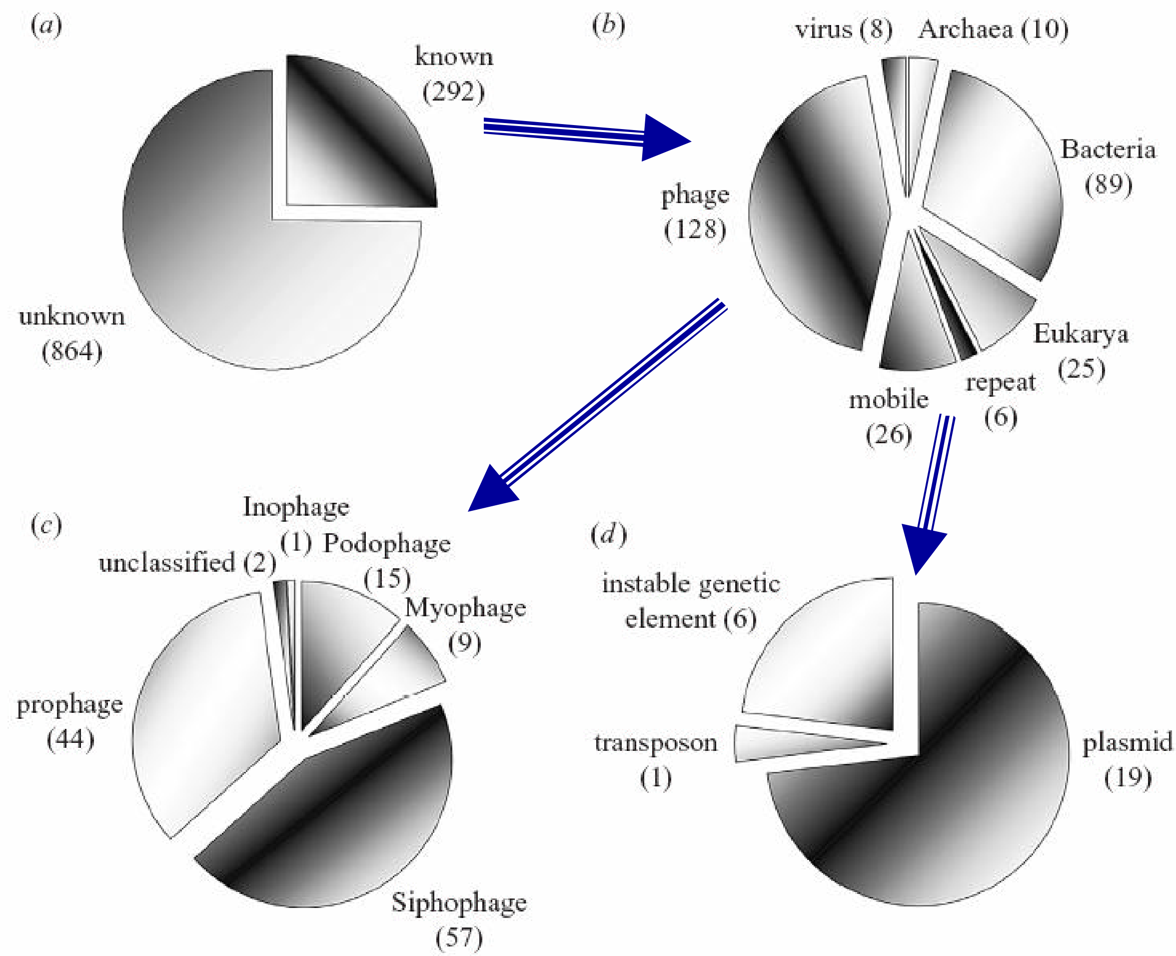


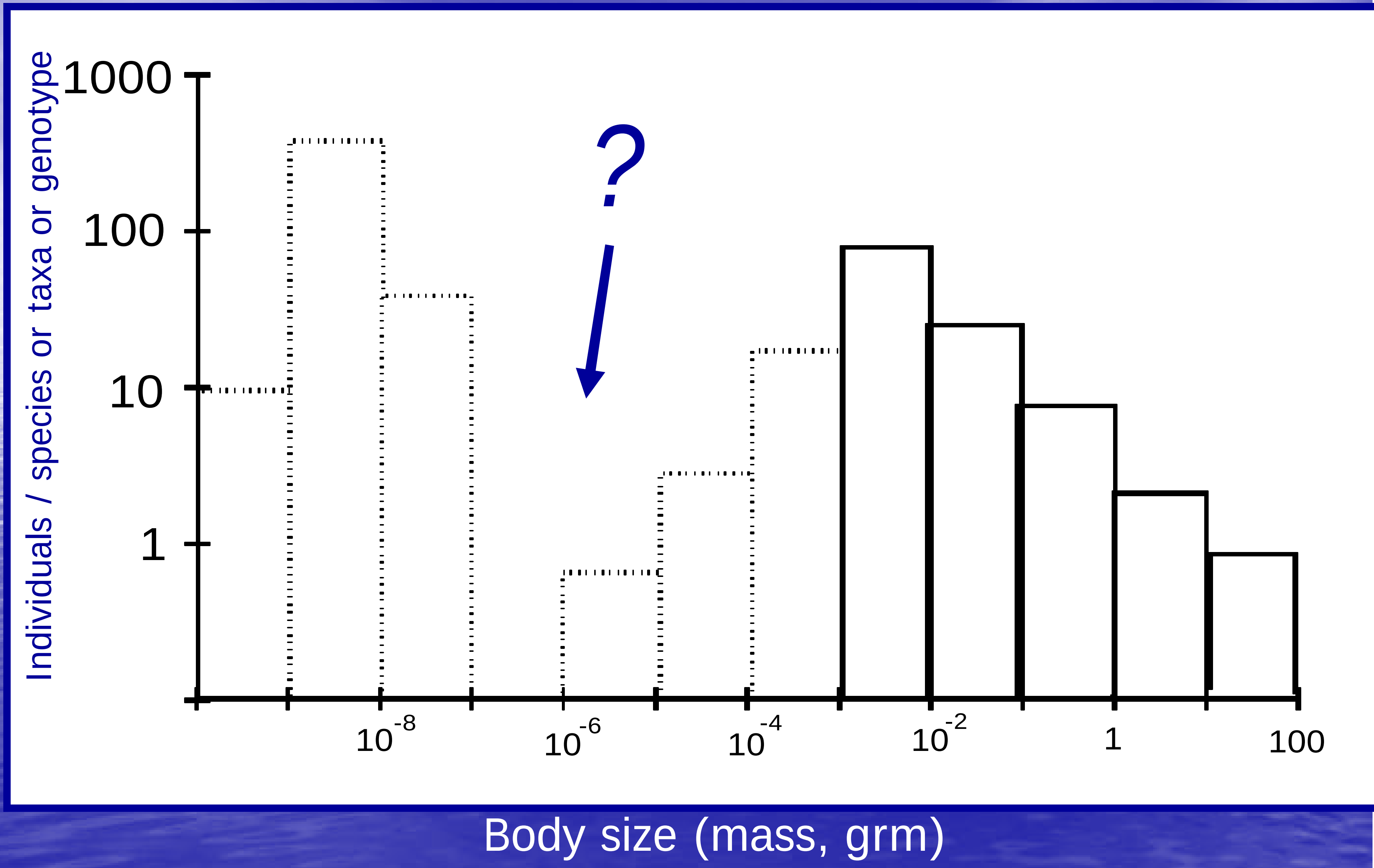
Figure 1. Genomic overview of the uncultured sediment viral community from Mission Bay, CA, USA, based on sequence similarities. (*a*) Number of sequences with a significant hit (*E*-value < 0.001) to GenBank. (*b*) Distribution of significant hits among the major classes of biological entity. (*c*) Families of phage represented in the sediment library. (*d*) Types of mobile element identified in the library.

Diversity and population structure of a near-shore marine-sediment viral community

Mya Breitbart[1], Ben Felts[2], Scott Kelley[1], Joseph M. Mahaffy[2], James Nulton[2], Peter Salamon[2] and Forest Rohwer[1,3*]

Proc. R. Soc. Lond. B (2004)

Salt marsh biodiversity by body size and abundance



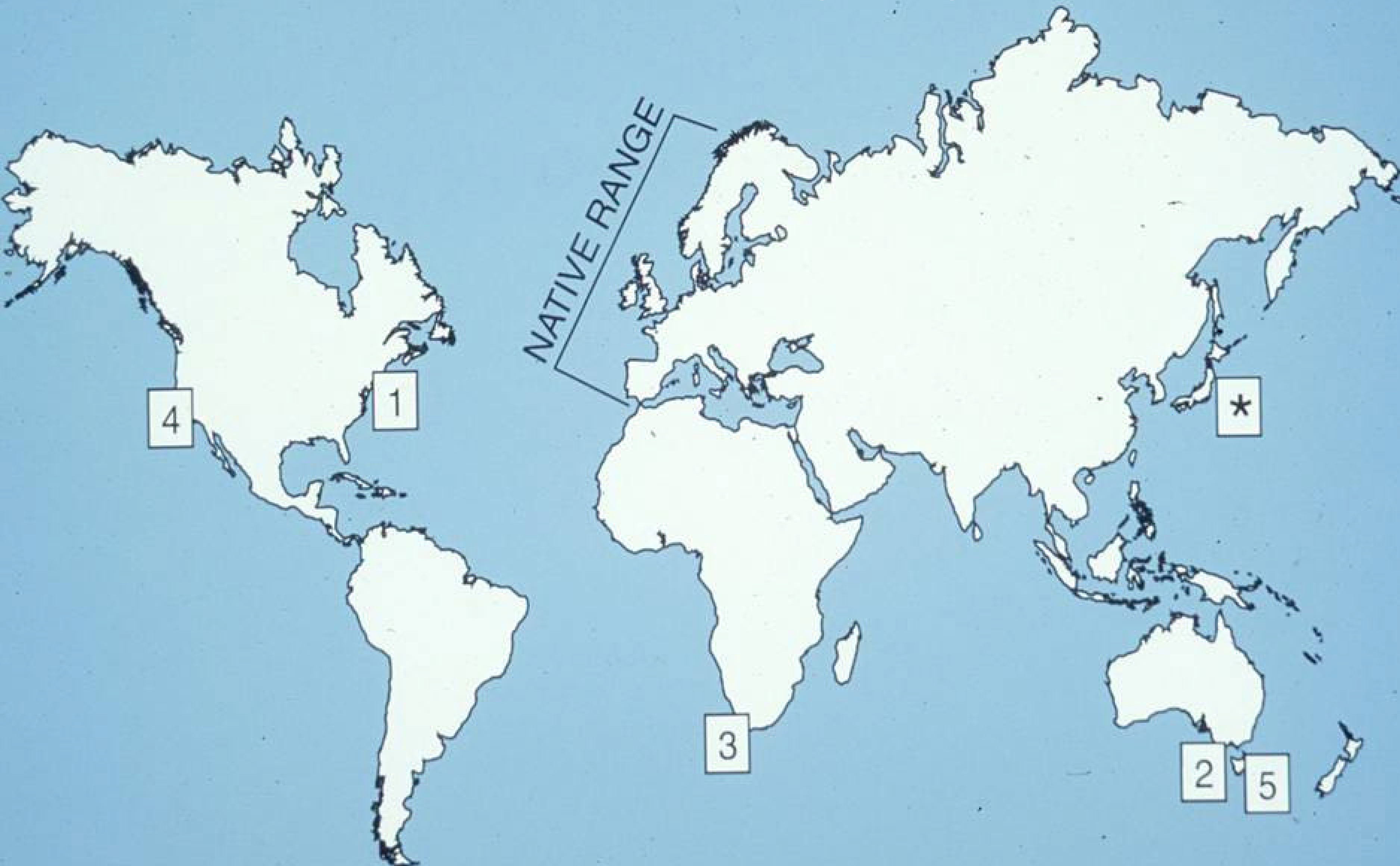
What happens in the absence of parasites?

- Examples from invasive species

Parasites and invasive species

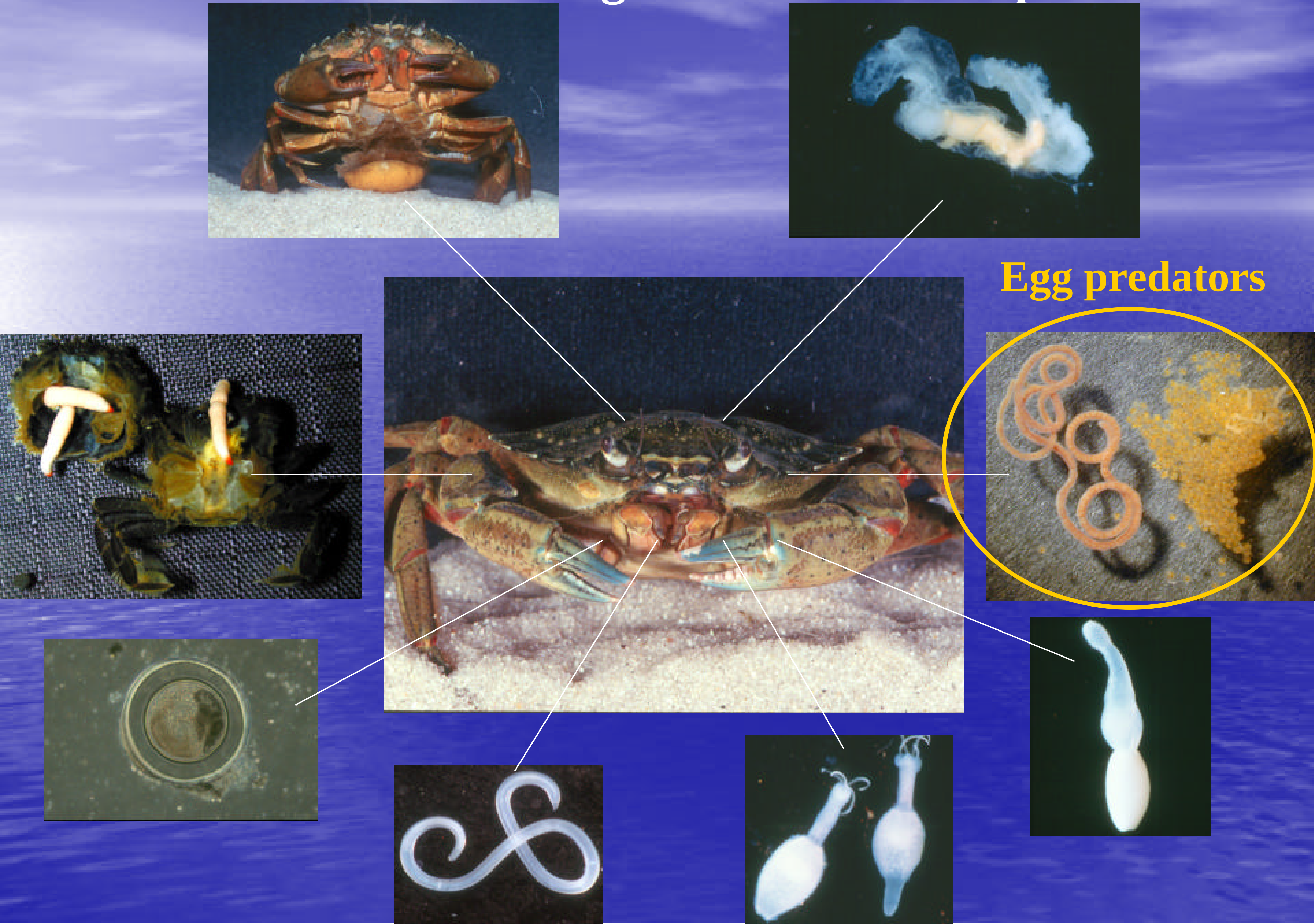
(with Mark Torchin, Kevin Lafferty, Armand Kuris, NCEAS)

Native and introduced range of green crab



Parasites of the green crab in Europe

Parasites of the green crab in Europe



Parasites of the green crab in Europe

Parasites of the green crab in Europe

Parasites of the green crab in Europe

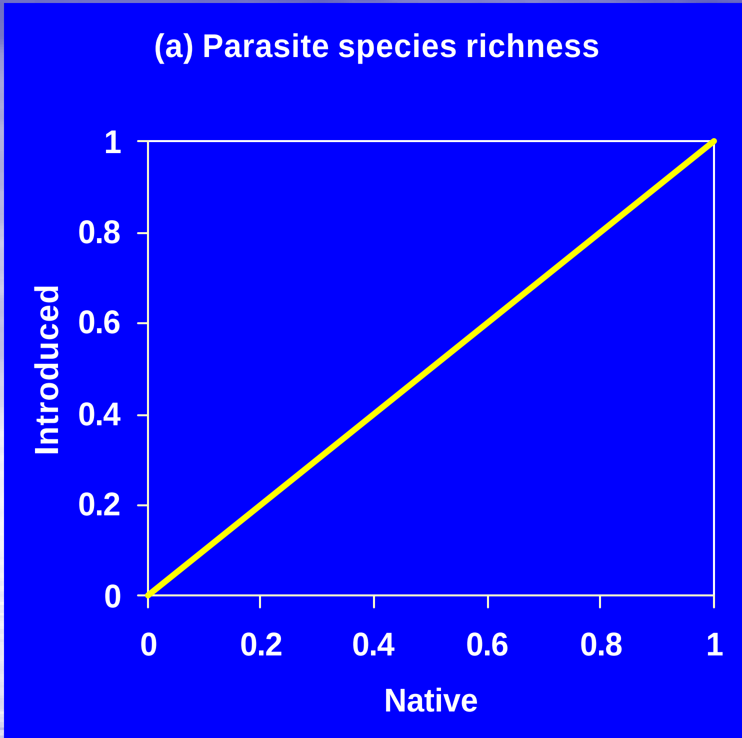
Parasites of the green crab in East Coast North America

Parasites of the green crab in Australia

Parasites of the green crab in West Coast North America

Parasites of the green crab in South Africa


Mark Torchin
(a further contribution to US obesity and over-consumption)



● = molluscs (N = 7)

■ = crustaceans (N = 3)

▲ = fishes (N = 6)

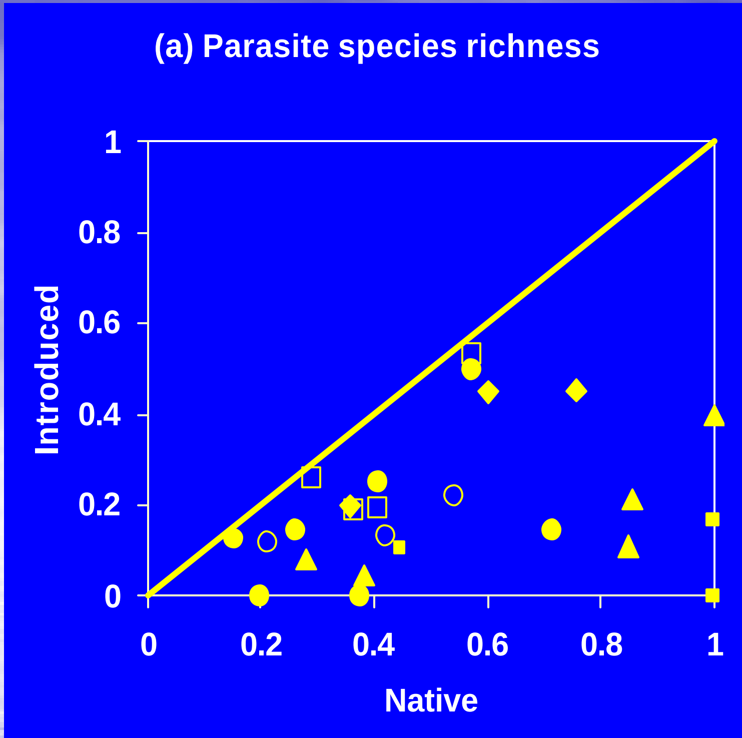
○ = amphibians and reptiles (N = 3)

◆ = birds (N = 3)

□= mammals (N = 4).

Torchin et al. 2003
Nature 421: 628-630

NCEAS



● = molluscs (N = 7)

■ = crustaceans (N = 3)

▲ = fishes (N = 6)

○ = amphibians and reptiles (N = 3)

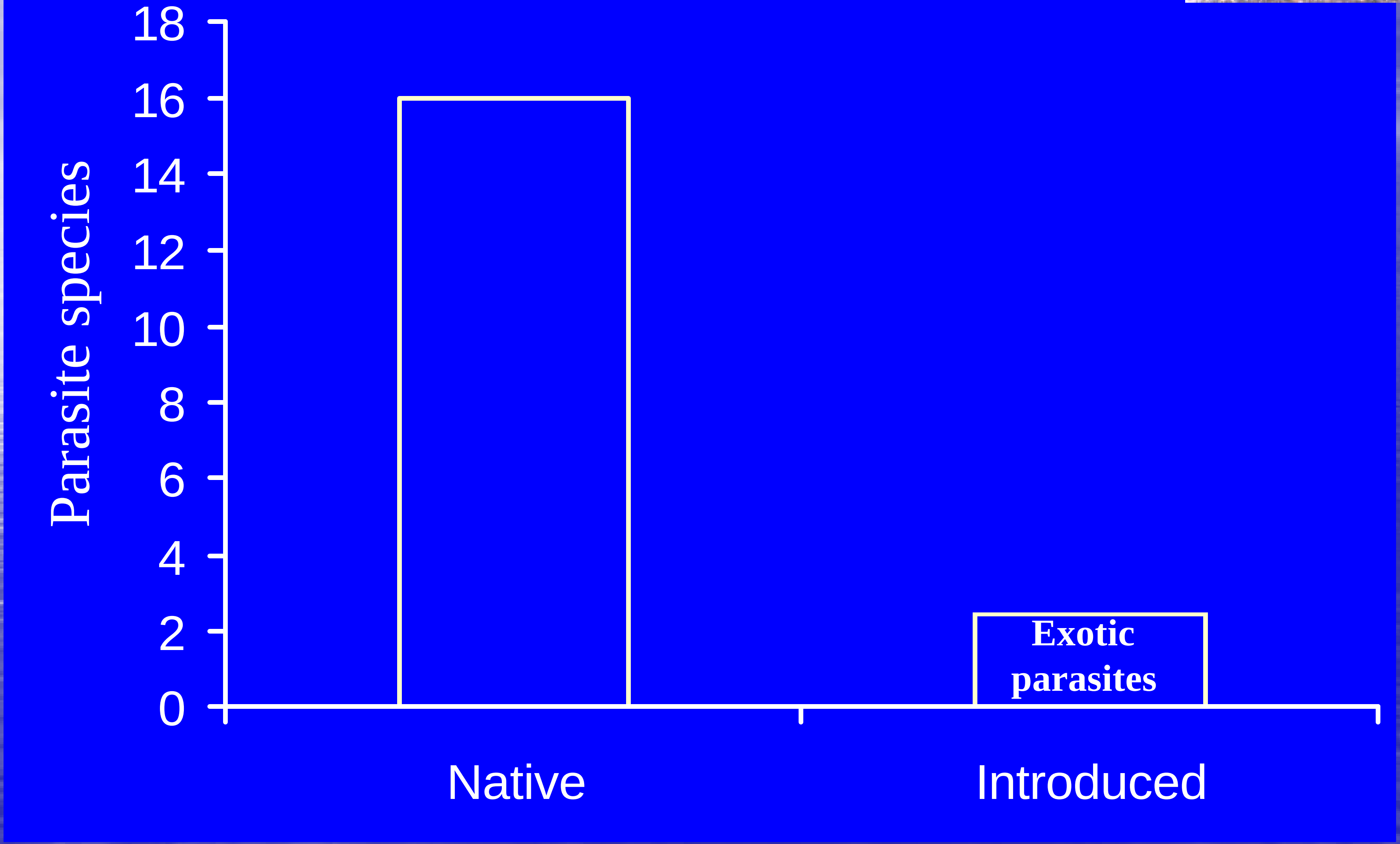
◆ = birds (N = 3)

□= mammals (N = 4).

Torchin et al. 2003
Nature 421: 628-630

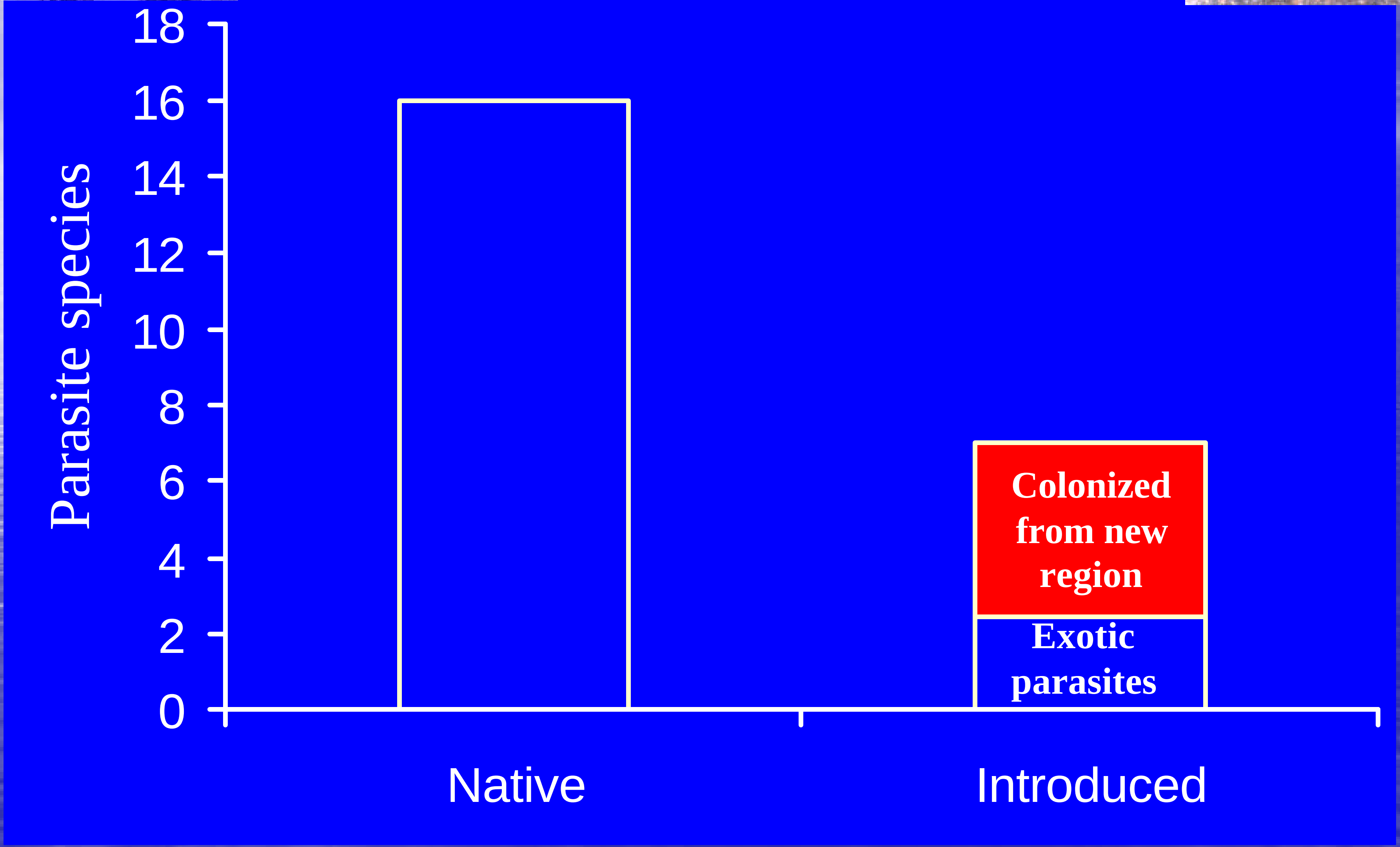
Release from parasites

(mean from 26 ANIMAL species)



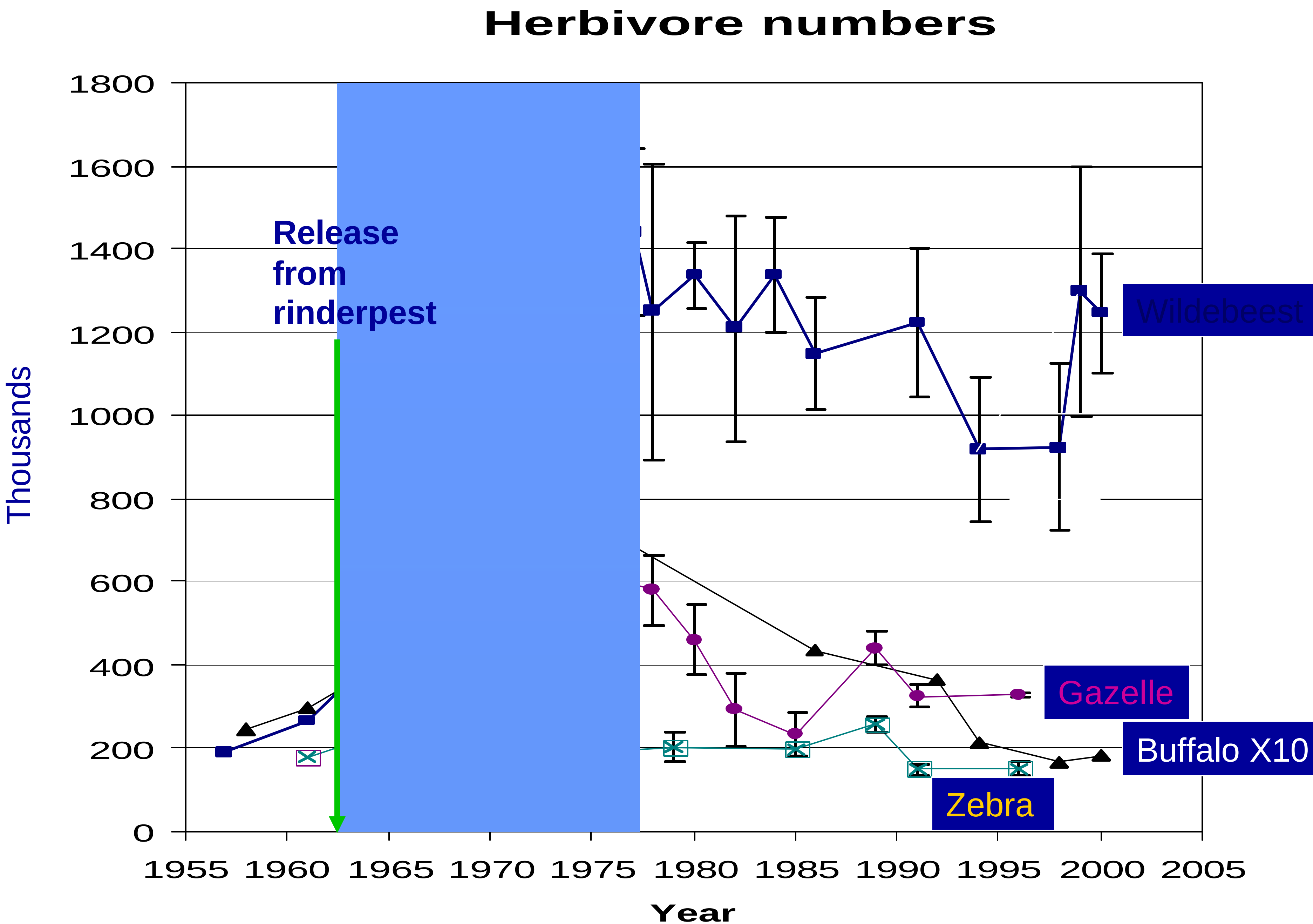
Torchin et al. 2003. *Nature* 421: 628-630

Release from parasites
(mean from 26 ANIMAL species)

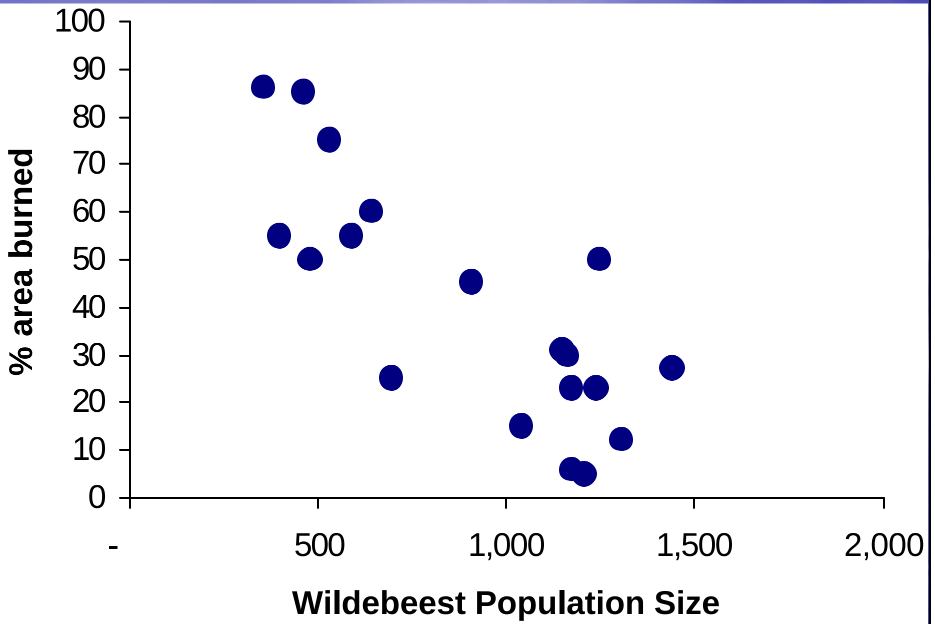


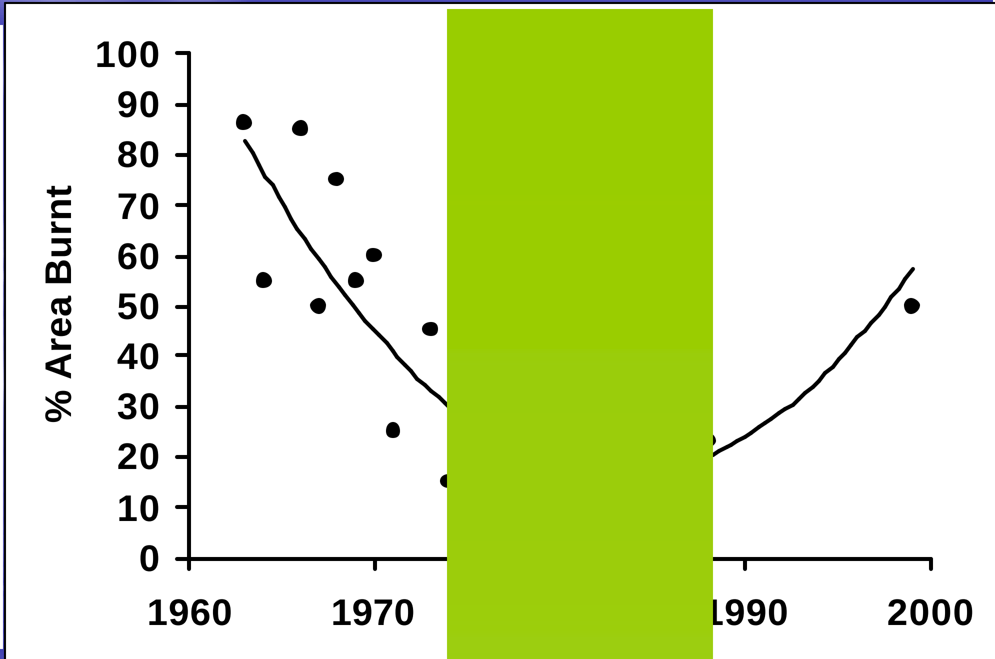
Torchin et al. 2003. *Nature* 421: 628-630

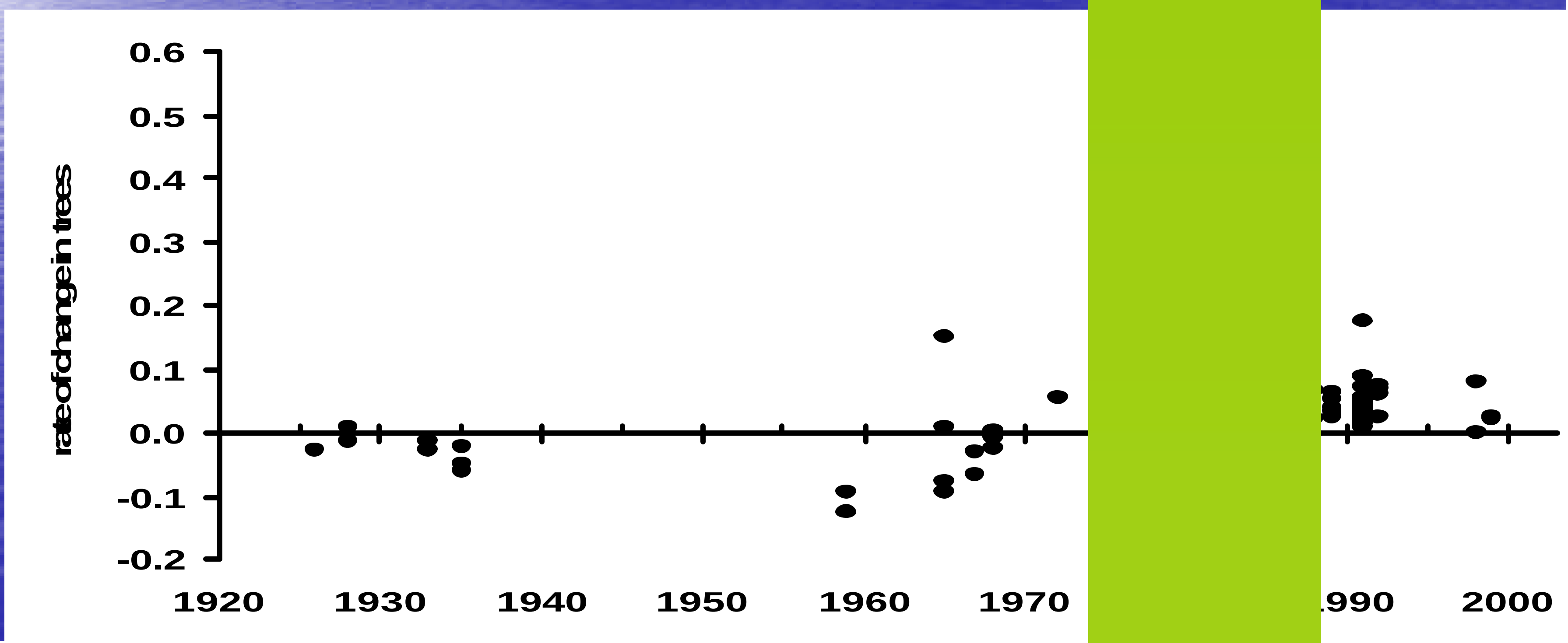
Serengeti
Predator-prey, or host-parasite?



Herbivore numbers
1800
1600
1400
1200
1000
800
600
400
200
0
Thousands
Release
from
rinderpest
Wildebeest
Gazelle
Buffalo X10
Zebra
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year


% area burned
100
90
80
70
60
50
40
30
20
10
0
-
500
1,000
1,500
2,000
Wildebeest Population Size


% Area Burnt
100
90
80
70
60
50
40
30
20
10
0
1960
1970
1990
2000


rate of change in trees
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
1920
1930
1940
1950
1960
1970
1990
2000

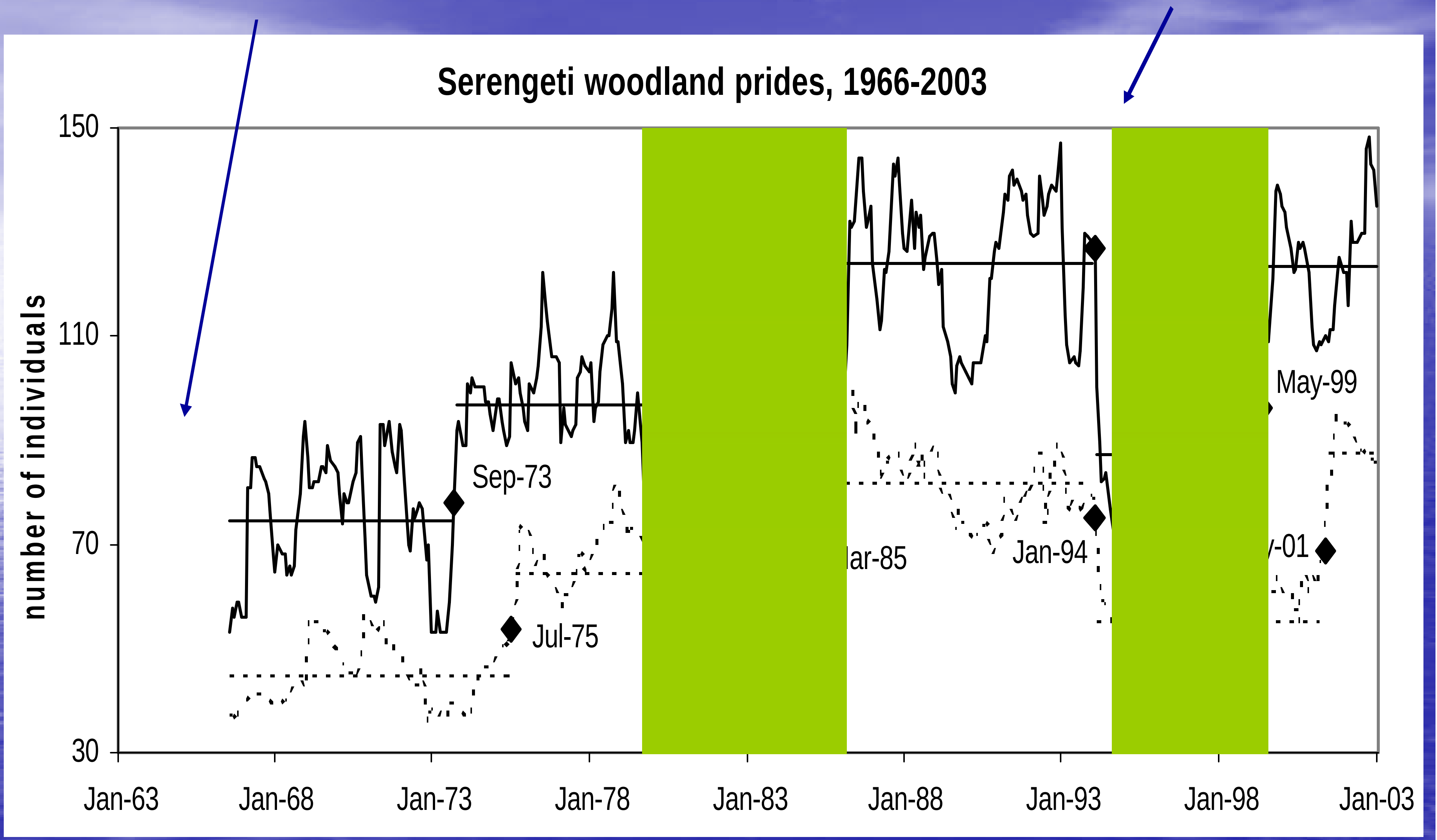
1980

1986

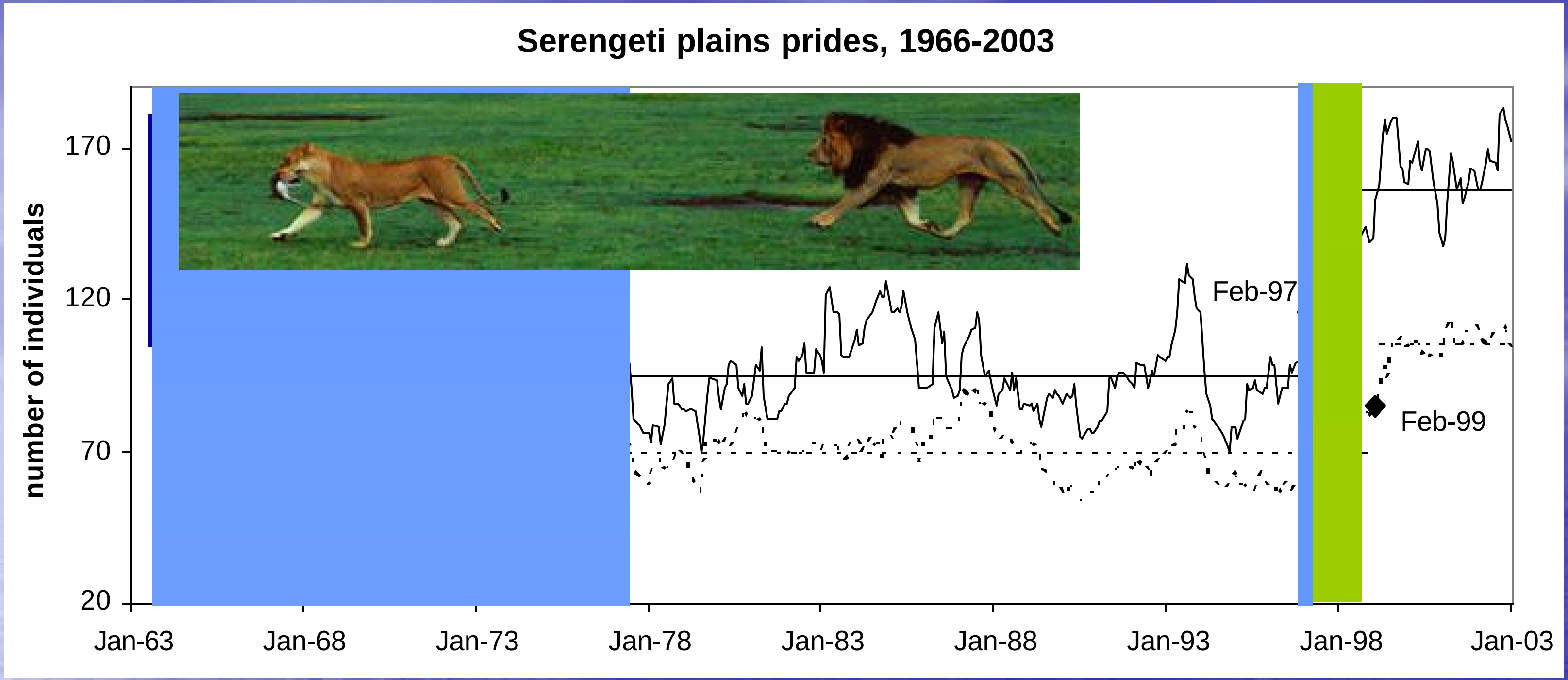
1991

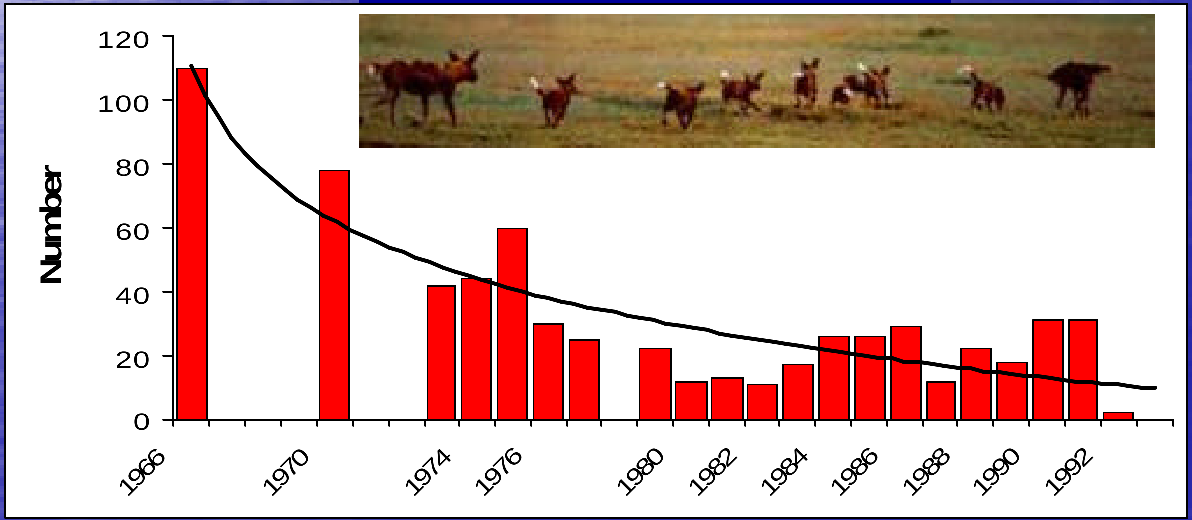
End of rinderpest in prey

CDV Outbreak



But...rinderpest produces cross immunity to distemper...'Ghost of immunity past'



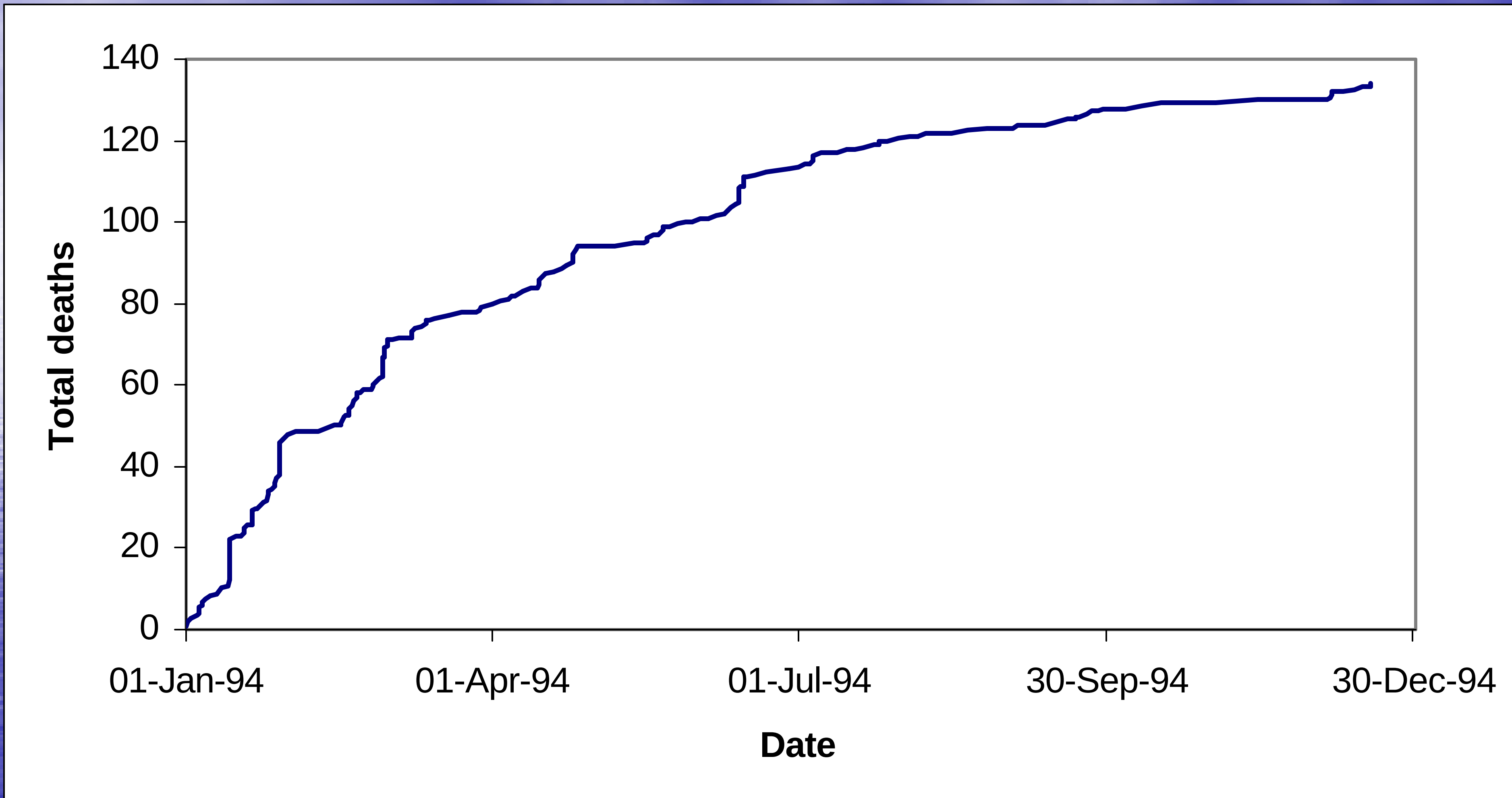


Serengeti Wild Dogs

Pathogens transmitted between species (wild & domestic)

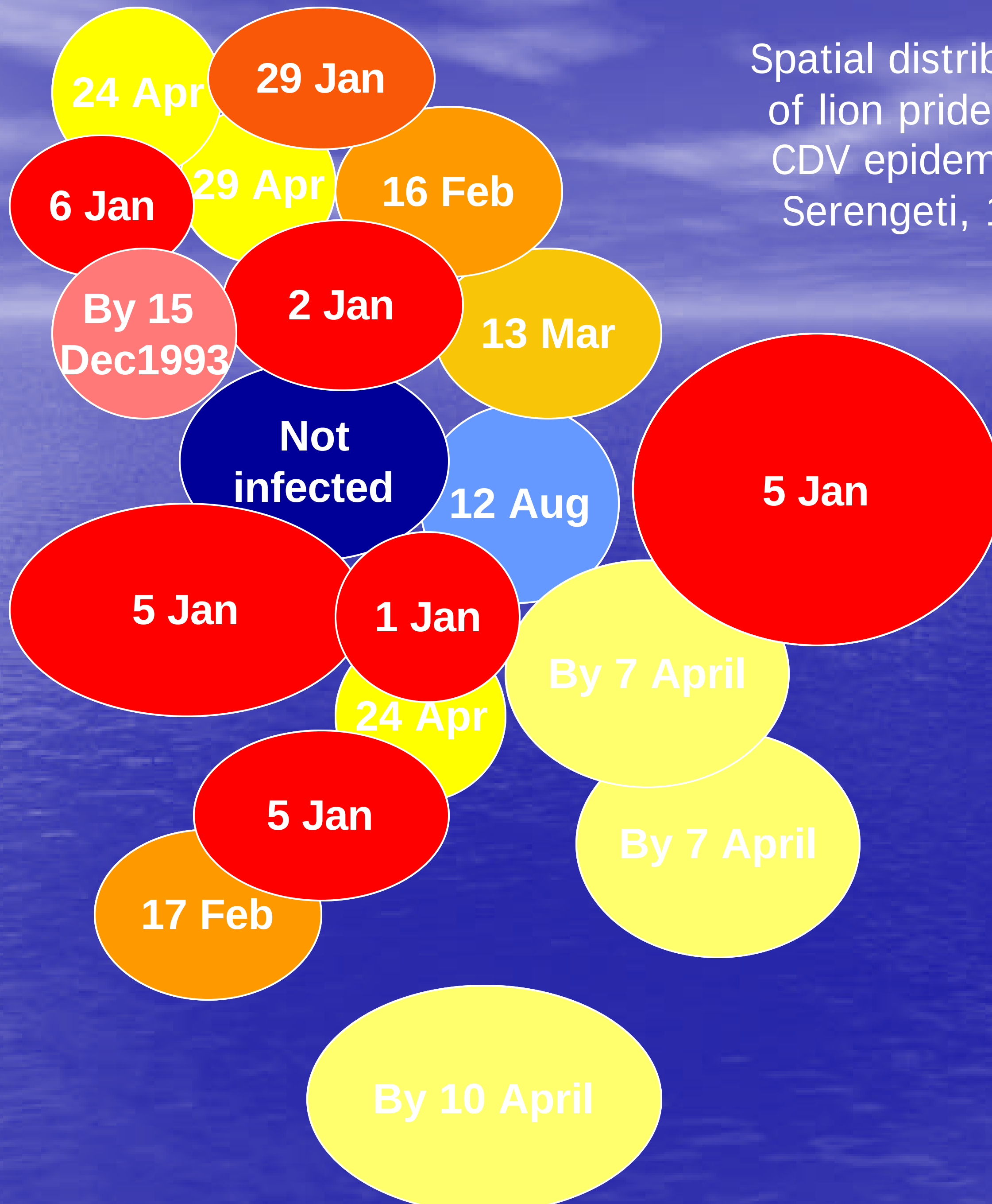
- The major disease problem in conservation biology
- Examples: Lions and CDV in Serengeti,
- Thanks to Ray Hilborn for video

Lion deaths in the Serengeti during 1994 CDV outbreak

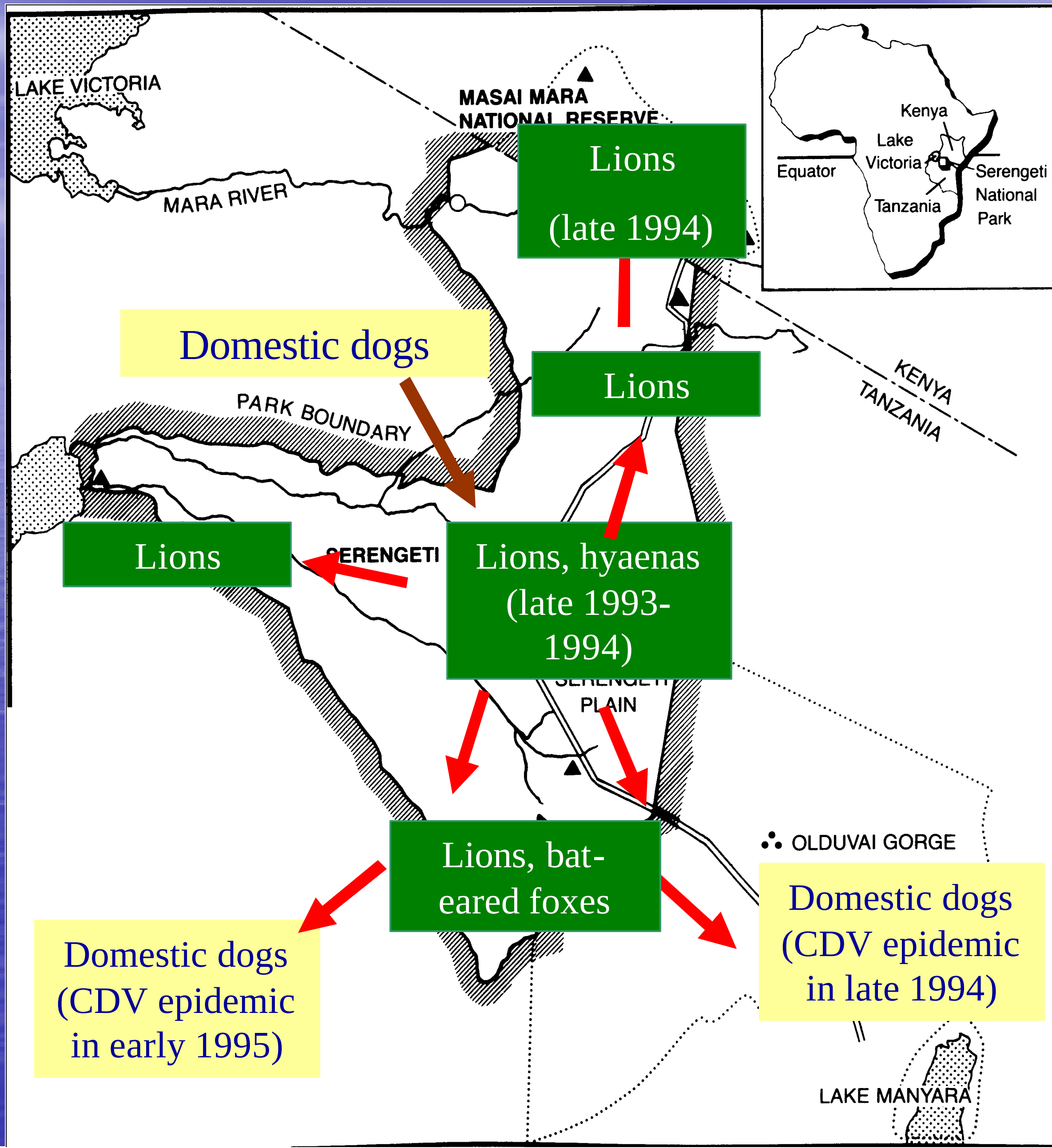


Long term lion studies by Craig Packer and colleagues

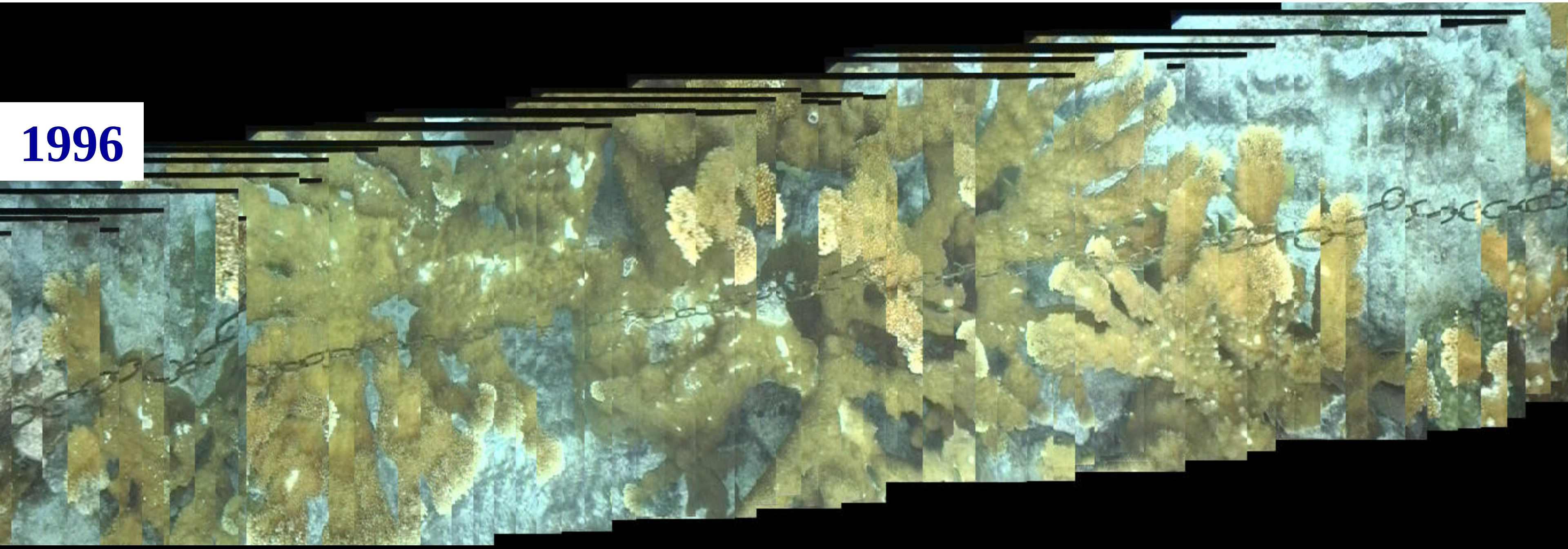
Spatial distribution of lion prides and CDV epidemic in Serengeti, 1994



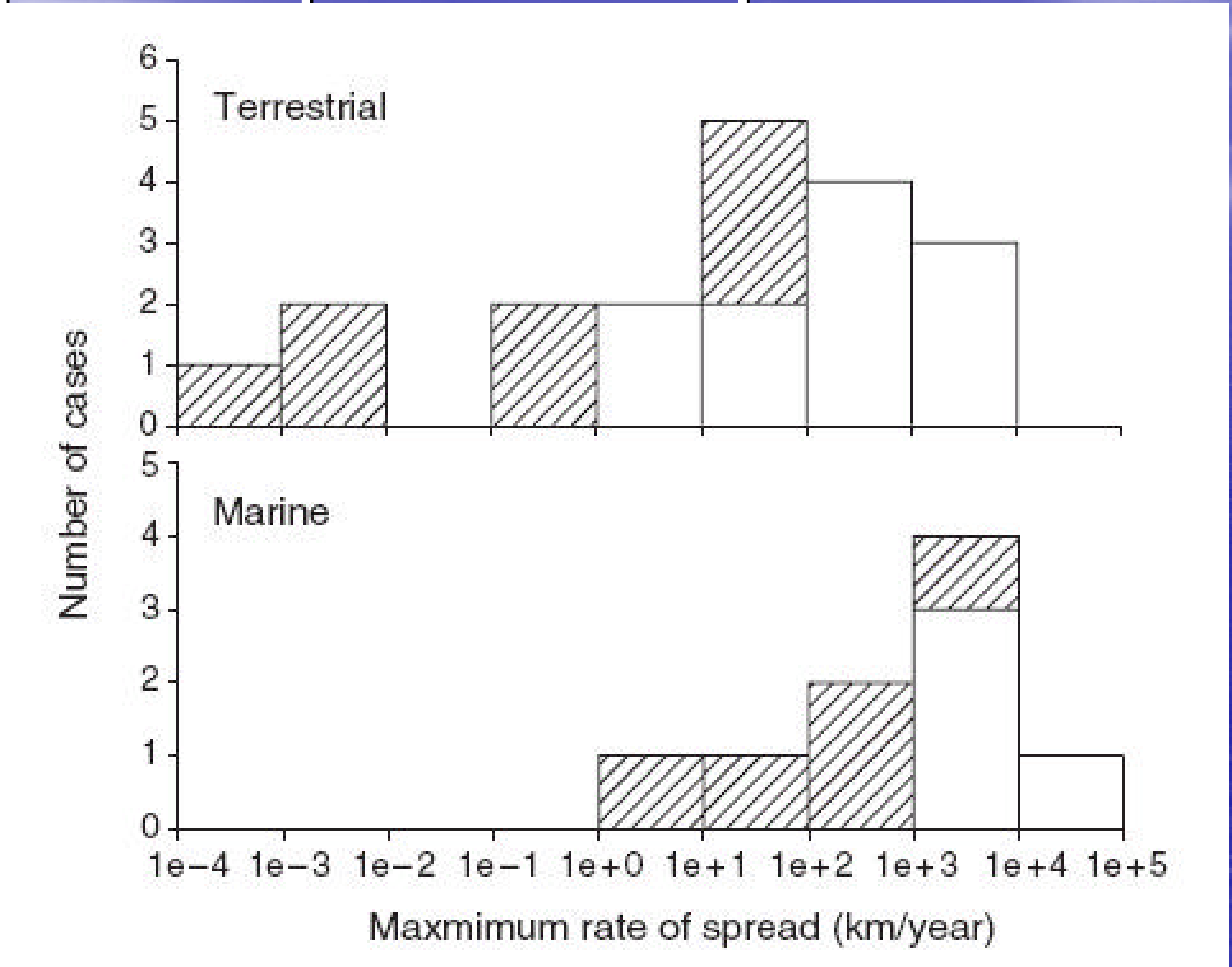
Spread of CDV during 1994 epidemic



Western Sambo Shallow, Station 2, Transect 300



Spatial spread of epidemics



Ecology Letters (2003) 6, 1062-1067

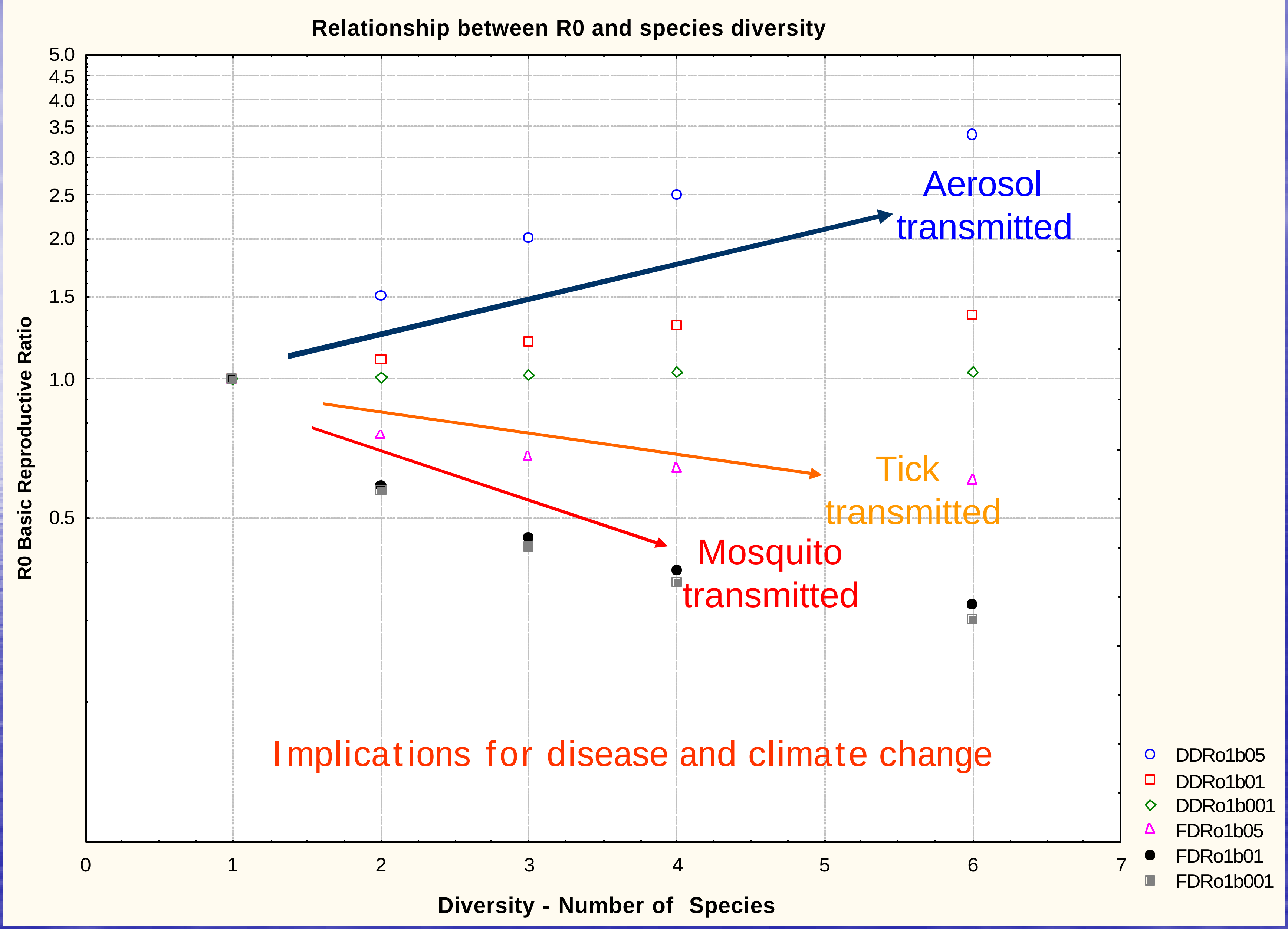
Table 1 Rates of spread of epidemics in marine and terrestrial environments, sorted by decreasing order of rate of spread

Habitat	Pathogen	Host	Max. rate of spread (km year^{-1})	Source	Date and location
Marine	Herpes virus	Pilchards	11 000	Murray *et al.* (2001b), Hyatt *et al.* (1997), Jones *et al.* (1997), Murray *et al.* (2000, 2001a)	1995: Australia
Marine	Herpes virus	Pilchards	5480	As above	1997: Australia
Marine	Bacterium	*Diadema* (sea urchin)	4990	Lessios *et al.* (1984), Lessios (1988)	1983: Caribbean
Terrestrial	RHV	Rabbits	4970	Kovaliski (1998)	1995: Australia
Terrestrial	Myxoma	Rabbits	4740	Ratcliffe *et al.* (1952)	1951: Australia
Marine	Morbillivirus	Seals	3970	Heide-Jorgensen & Härkönen (1992), De Koeijer *et al.* (1998), Swinton *et al.* (1998)	1988: Baltic
Marine	Morbillivirus	Striped dolphins	3230	Aguilar & Raga (1993), Cebrian (1995)	1990: Mediterranean
Terrestrial	West Nile Virus	Birds	1150	http://cindi/usgs/gov	1999: USA
Marine	Amoeba	Sea urchin	936	Miller & Colodey (1983)	1980: Nova Scotia
Marine	White pox bacterium	Coral	600	Richardson *et al.* (1998)	1995: Florida
Terrestrial	Myxoma	Rabbits	600	Fenner & Fantini (1999)	1952: France
Terrestrial	Mycoplasmal conjunctivitis	House finch	512	Dhondt *et al.* (1998)	1994: Eastern USA
Terrestrial	Rinderpest	Ungulates	500	Dobson & May (1986)	1887: Africa
Terrestrial	RHV	Rabbits	180	Villafuerte *et al.* (1995)	1988: Spain
Terrestrial	Rabies	Canids	60	Anderson *et al.* (1981)	1930: Europe
Terrestrial	Rabies	Racoons	47	Childs *et al.* (2000)	1991: North America
Terrestrial	Nuclear polyhedrosis virus	Forest tent caterpillar	32	Entwistle *et al.* (1983)	1950: Canada
Terrestrial	Baculovirus	Rhinoceros beetle	26.7	Entwistle *et al.* (1983)	1970: Tonga
Marine	Rickettsia	Abalone	20.7	Lafferty & Kuris (1993)	1985: California
Terrestrial	Dutch elm disease	American elm	11.5	Gibbs (1978)	1944: Quebec
Terrestrial	Sarcoptic mange	Chamois	7.65	Fernandez-Moran *et al.* (1997)	1993: Spain
Terrestrial	Bovine tuberculosis	African Buffalo	6	De Vos *et al.* (2001)	1990: Africa
Marine	Black band disease cyanobacterium	Coral	1.2	Bruckner *et al.* (1997)	1992: Jamaica
Terrestrial	Nuclear polyhedrosis virus	Spruce sawfly	0.75	Entwistle *et al.* (1983)	1972: Scotland
Terrestrial	*Phytophthora cinnamomi* fungus	Eucalyptus	0.4	Weste & Marks (1987)	*c.* 1960: Victoria
Terrestrial	*Phytophthora cinnamomi* fungus	Banksia	0.0012	Hill *et al.* (1994)	*c.* 1960: Western Australia
Terrestrial	*Armillaria ostoyae* fungus	Douglas fir	0.0013	Peet *et al.* (1996)	1986: Canada
Terrestrial	*Inonotus tomentosus* fungus	Spruce	0.0002	Hunt & Peet (1997)	*c.* 1890: Canada

We have reported the upper limit, where the original source gives the rate of spread as a range. The dates given are the year that the epidemic commenced. Multiple rates are given for the same host–pathogen interaction only where the epidemics are demonstrably separate events.

Number of Coral Species with Disease

	WH	BB	OD	Diseased Species	Percent Diseased
1996	3	2	8	11	27 %
1997	22	4	22	28	68 %
1998	28	7	28	35	85 %
Increase (96-98)	833 %	250 %	250 %	218 %	



Relationship between R0 and species diversity
R0 Basic Reproductive Ratio
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1
2
3
4
5
6
7
Diversity - Number of Species
Aerosol transmitted
Tick transmitted
Mosquito transmitted
Implications for disease and climate change
DDRo1b05
DDRo1b01
DDRo1b001
FDRo1b05
FDRo1b01
FDRo1b001

Conclusions

- Pathogens are a major component of biodiversity.
  - Interesting implications for 'intelligent design'!
- In a healthy ecosystem consideration of parasites may double the number of species
- Absence of parasites is beneficial to invasive species.
- Shared pathogens and spillover create serious health problems for humans and endangered species.
- Biodiversity creates an important disease buffer particularly against vector transmitted pathogens.